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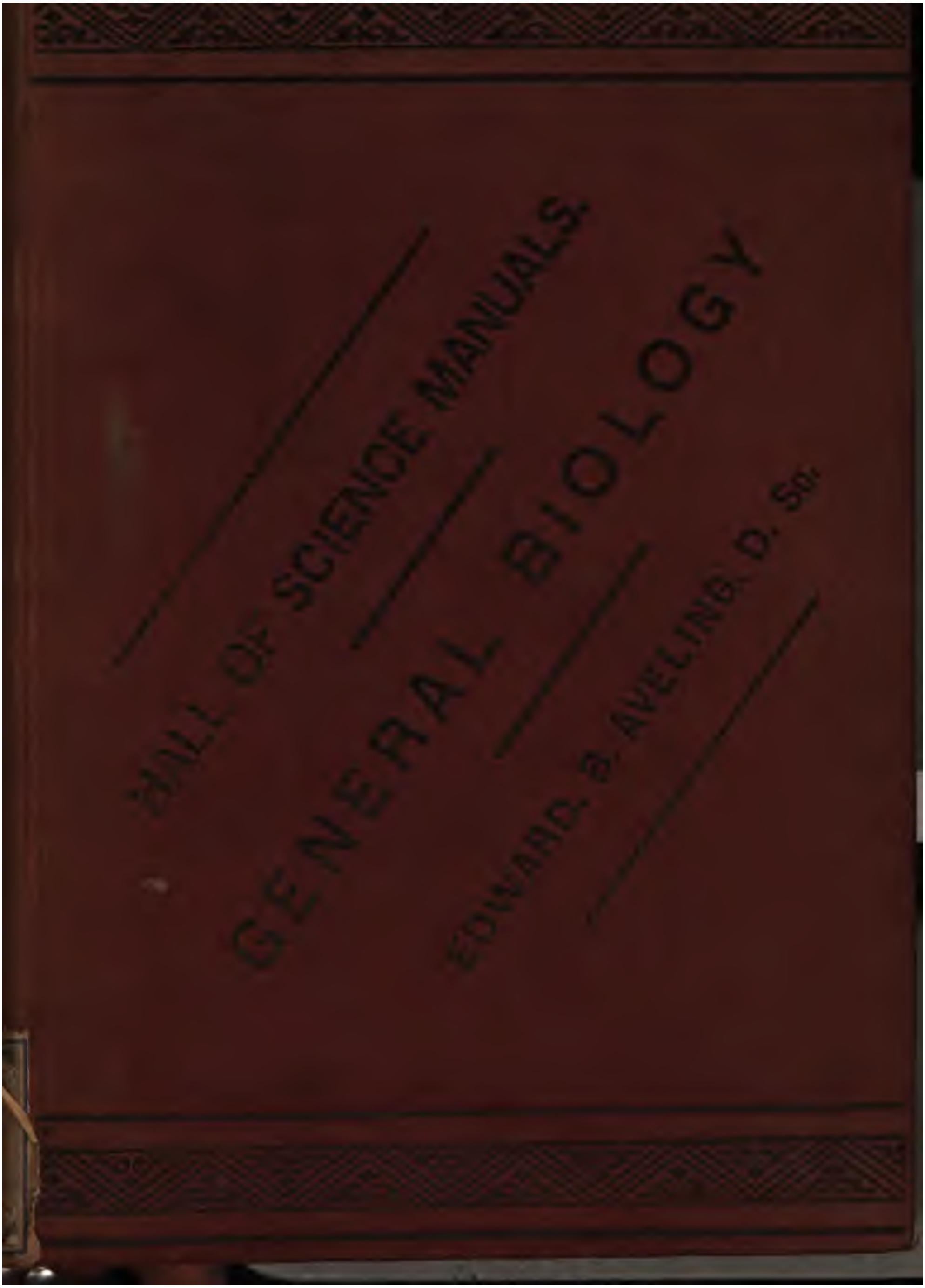

HALL OF SCIENCE MANUALS.

GENERAL BIOLOGY

EDWARD. B. AVELING, D. Sc.

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HALL OF SCIENCE MANUALS.

GENERAL BIOLOGY,

Theoretical and Practical.

BY

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PREFACE.

THE present work is designed as an aid to students of Biology, and especially to those intending to offer themselves for examination in the first stage in that subject at the Science and Art Department of the Committee of Council on Education, South Kensington.

Whilst the book is fashioned upon the lines of that examination, its author hopes it may be of use to other students who may desire to gain a knowledge of the typical forms of living things. The general plan of the work is as follows. A. Introduction. After defining Biology, the general plan upon which we shall study each animal and plant will be laid before the reader, and the nature of the practical work so absolutely necessary, and of the apparatus required therefor, will be dealt with. B. Certain typical living beings will be studied in succession. The order in which these will be investigated will deviate from that in which these plants and animals are named in the syllabus. The particular order selected in this book is chosen because it is one in which those first studied are the simplest organisations in structure, and those last studied are the most complex. An attempt has been made to arrange the living things to be investigated in a regular succession, that will proceed from the simplest, through ever-increasing stages of complexity, to the most complex. No pretence is here made that the scheme represents the exact order of the evolution of these living things. All that is claimed is that, as far as the structures of the individual plants and animals are concerned, our list will be found to begin with those of the most rudimentary make, and proceed systematically to the more complex ones. C. Some of the questions given in past years at the examination will be considered, and suggestions made as to the method of answering. A few original ones for guidance of the student will be added. D. A glossary, containing derivations and definitions, and, where they are needed, examples of the chief scientific terms, will conclude the volume.

GENERAL BIOLOGY.

CHAPTER I.

A.—INTRODUCTION.

Biology will be defined. The general plan will follow on which the living beings to be considered will be studied. The nature of the essential practical work will be discussed.

I. Definition of Biology.—βιος = life, λογος = science. Biology is the study of living things. Without pausing to discuss the exact meaning of the word "life," we agree that Biology is the study of those forms of matter that are by common consent called living.

In this work it is impossible to study the whole or even a considerable fraction of living forms. It is possible to study certain typical cases taken from different levels in the great scale of living things, and thus to obtain a general idea of the structure and functions of plant and animal bodies. Each of the instances chosen by the Science and Art Department is one of two things. Either, as in the foremost that we shall study, it is a form of living things necessary to be investigated in order to gain a clear idea of the nature of living matter as distinct from non-living, or, as in the later objects of inquiry, it is a plant or animal that is a type of a great group, and in its life-history gives us the key to that of many of its fellows.

II. Plan of Work.—Nothing should be more strongly impressed upon the young student than the necessity of system in his work. A plan will therefore be laid before the reader to which the writer will adhere in his account of each plant and animal. Although this particular plan would by no means be insisted upon as essential for everyone—*a* plan is essential, and the student is advised either to use this or some kindred scheme in all his work. There should be a place for every newly-acquired fact, whether it be gained by reading, or from a lecture, or from the observation of the student himself. He should accustom himself to say, as each fresh acquisition is made: "that fact belongs to such and such a division of my plan, fits in under such and such a head." The adoption of such a plan as this aids in the following ways. By fixing the fact more firmly in the mind. For the very effort to think where the fact is to be located concentrates attention more fully upon it and renders it more easily remembered. By rendering the student more able to place his hand at once upon any special fact that may be required. By enabling him at an examination to reproduce his knowledge with much greater readiness. Asked for the life-history of a Hydra, he has not to rack his brains in frenzied fashion in order to collect a number of isolated facts, but goes steadily through his plan, placing truths under their respective heads, and finds at the end that nothing of importance has been omitted. The plan under which each special living thing will be studied is as follows:—(*a*) Structure, (*b*) Digestion, (*c*) Absorption, (*d*) Circulation, (*e*) Respiration, (*f*) Secretion, (*g*) Nervous System, (*h*) Sense Organs, (*i*) Motor Organs, (*k*) Reproduction, (*l*) Development, (*m*) Classification.

(*a*) *Structure.* The general build of the plant or animal. Its cells, fibres, vessels, tissues, skeleton, and the general arrangement of its organs. (*b*) *Digestion.* The nature of its food, and the means by which it seizes that food and digests it. (*c*) *Absorption.* The method whereby food, after it has undergone the process of digestion, is carried into the blood system. (*d*) *Circulation.* The nature of the nutritive fluid and the manner in which it is circulated round the body. (*e*) *Respiration.* The study of the way in which the gases of this fluid are maintained in healthful condition. (*f*) *Secretion.* The study of the way in which the liquids and solids contained in this fluid are maintained in a healthy condition. (*g*) *Nervous System.* An account of the brain, spinal cord, ganglia, and nerves, that the being may possess. (*h*) *Sense Organs.* Those of touch, taste, smell, hearing, and sight. (*i*) *Motor Organs.* The muscles, the limbs, the various means of locomotion. (*k*) *Reproduction.* Thus far the life of the individual only has been considered. Here that of the species comes under consideration, and the methods and organs of reproduction are studied. (*l*) *Development*. This includes the history of all the changes from the first impregnation of the egg until the complete plant or animal is formed. (*m*) *Classification*. The position of the living thing in our artificial system of classification, and its standpoint in relation to other living things.

III. Practical Work.—This book, and all the other books upon Science that ever were written, will be of little use unless begun, considered, and ended hand in hand with practical work.

Every plant or animal must be seen, examined, dissected. The only value of a book like this is to guide the student in his observations, and to sum up the results of them, until such time as he has made enough progress to construct a summing-up for himself. At the end of the account of each being, I shall place a few directions as to dissections to be made, and specimens to be prepared for microscopic investigation, that will, I hope, be of service to those who are teaching themselves or teaching others. The student should have the following things for practical work.

(*a*) Microscopes and appendages.—(1) A simple one for dissection of flowers. (2) A compound microscope, with 1 in., $\frac{1}{4}$ in., and $\frac{1}{8}$ in. objectives. (3) Glass slides. (4) Cover glasses. (5) A razor, ground flat on one side, for making sections. (6) Needles, mounted in wooden handles, for teazing out specimens. (7) Camel's hair brushes. (8) Paraffin, in which to imbed objects before making sections of them.

(*b*) Knives.—(1) A small case of knives, such as are used by oculists, for the dissection of flowers and minute animals. (2) A larger case, such as medical students use, for dissection of the larger animals.

(*c*) Test-tubes and re-agents.—(1) A dozen test-tubes in a stand. (2) Re-agents: acetic acid, glycerine, iodine tincture, magenta solution, potash, sulphuric acid, chloroform, distilled water.

(*d*) Drawing-book.—*Everything that is seen with the unaided eye, or through the microscope, must be drawn by the student*, and explanatory notes or letters, referring to the different parts of the drawing, must be inserted. These last are very necessary for the student, and, on occasion, for any one else who may see his sketches.

CHAPTER II.

B.—TYPES OF LIVING BEINGS.

I. BACTERIA.

(*a*) *Structure.*—The methods of occurrence of these organisms, their size, their general structure, their different forms, the effects on them of re-agents and of temperature, will be considered.

(1) Occurrence. These beings, amongst the lowest forms of living things, are found in connexion with diseased conditions, in connexion with fermenting bodies. The red color noticed in mouldy bread is due to Bacteria. Such diseases as diphtheria, typhus fever, cholera, appear to depend on their presence. Many cases of fermentation are due to the presence of these organisms, and the putrefaction of plants and animals seems to result from fermentations originated by them. Students who may wish to prepare these organisms without the help of disease will find the best plan is to infuse hay in warm water for thirty minutes; filter and keep the filtrate in a warm place. When the hay infusion becomes turbid, a drop of it, under a high power, will be found full of Bacteria.

(2) Size. They are very minute. Hence arises a great likelihood of the confusion of other minute bodies with these on the part of the young student. In transverse diameter they vary between $\frac{1}{1100}$ m. m., and $\frac{1}{375}$ m. m. Their longitudinal diameter is much greater than this, but is too variable to be stated with any precision.

(3) General structure. They are masses of protoplasm of various shapes, that are in many cases not surrounded by a distinct wall.

As this is the first time that the word "protoplasm" occurs in this book, let us settle, as clearly as we can, what we mean by it. Protoplasm is derived from πρωτος=first, πλασμα=formative matter, *i.e.*, matter that can be shaped into other substances, such as the tissues of a plant or of an animal body. Protoplasm is the "physical basis of life." Wherever life is protoplasm appears to be. It is semi-fluid, granular in appearance, consists of the four elements, carbon, hydrogen, oxygen and nitrogen. It has the power of contractility. A mass of it changes its form, and is now longer, now shorter along the same diameter. This protoplasm, or formative matter, adheres to iodine. So that if the specimens under investigation are treated with iodine, their protoplasm stains brown, and this re-action with iodine occurs with every piece of formative matter, ready to become actual plant or animal substance. If the piece of protoplasm is without an enveloping wall, as in many Bacteria, and consists of protoplasm, and protoplasm only, we have a plastid. If the protoplasm is invested by a distinct wall that is wholly destitute of structure, the being is a cytod; for a plastid is a free mass of protoplasm, and a cytod is a mass of protoplasm enveloped by a distinct wall. This wall is more transparent than the contents. In the compound forms it is only to be seen just where the joints making up the compound form come in contact one with the other. In the still condition of these organisms the wall is exceedingly gelatinous. This still stage, with its thick envelope of jelly-like material, is known as the zooglœa stage. (Ζωον = life, γλοιος = viscid.)

(4) Different forms of Bacteria. The name "Bacteria" is given to various forms of living things. These plastids or cytods may be solitary or grouped together. When they occur alone they may either be spherical, as in certain forms of Micrococcus, or rod-like, as in the true Bacteria. When they occur aggregated together, they may be of the form of rudimentary cells, as in other forms of Micrococcus, or as rod-like structures joined together. Even this last arrangement admits of sub-division, as rod-like parts may be conjoined end on, or at an angle (not of 180°), or wound in a spiral. A little table will make these different forms more clear.

- BACTERIA.
  - Isolated
    - Spherical—*e.g.*, Micrococcus.
    - Rod-like—*e.g.*, Bacterium.
  - United
    - Spherical—*e.g.*, Micrococcus.
    - Rod-like
      - Parts joined end on—*e.g.*, Bacillus.
      - Parts joined at an angle—*e.g.*, Vibrio.
      - Parts joined spirally (often a double spiral)—*e.g.*, Spirillum and Spirochæte.

(5) Effect of reagents and temperature. (*a*) Iodine. The protoplasm or formative matter adheres to iodine; so that if the specimens under investigation are treated with iodine the protoplasm stains brown, and this reaction of iodine occurs with all formative matter ready to be, but not yet actually, transformed into a plant or animal substance. The outer wall, where it exists, is not stained with iodine, as is the protoplasm. The wall is no longer of formative matter. It is formed material, and formed material never stains with iodine. (β) Magenta or carmine solution also stains protoplasm. (γ) A temperature of 0° kills Bacteria. A temperature of 60° kills them. These are their limits of temperature. They thrive best at 30°. (δ) Desiccation. They can survive a lengthy period of drying or desiccation. On the advent of moisture they revive.

(*b*) *Digestion.*—Bacteria feed on decaying organic matter. Hence their name of saprophytes (*σαπρος*=putrid, *φυτον*= plant). We shall find hereafter that most plants feed on inorganic or mineral things, most animals on organic matters. But certain living things, of which it is difficult to say if they are plants or animals, feed on organic matters that are passing down by decay into the simpler condition of mineral gases. These living things, that feed on matter in the intermediate stage between the organic and inorganic, are called saprophytes. In the laboratory we are able to provide Bacteria with a fluid in which they will live and grow. It is known as Pasteur's fluid, and is named after the great French experimenter. In his experiments he used the ash of the yeast plant, and this fluid contains the substances present in the yeast plant, together with one or two other bodies. The composition of Pasteur's fluid is: potassium phosphate, $K^2 H P O^4$, 1 decigram; magnesium sulphate, $Mg S O^4$, 1 decigram; calcium phosphate, $Ca_3 2 P O^4$, 1 decigram; ammonium tartrate, $(H^4 N)^2 C^4 H^4 O^6$, 5 grams; water, H^2O, 430 cubic centimetres. The student will see that the fluid contains the following chemical elements: potassium, K; hydrogen, H; phosphorus, P; oxygen, O; calcium, Ca; magnesium, Mg; sulphur, S; nitrogen, N; carbon, C.

Now, when organisms such as Bacteria are burned, and the ash elements analysed, the elements carbon, hydrogen, nitrogen, sulphur, phosphorus, potassium, magnesium, calcium, are found to be present. We see, therefore that Bacteria thrive in a fluid that contains these elements, and that they have the power of building up, out of mineral salts, the organic protoplasm of which they consist. It is on this ground mainly that they are recognised as living things. Their food is taken in by the whole of the general surface. There is no definite mouth or digestive apparatus.

(*c*) *Absorption.*—As in many of the lower living beings, the function of absorption is merged with that of digestion. The whole surface of the Bacteria absorbs food. But that very absorption is here in reality a digestive process, and results in the in-taking of food.

(*d*) *Circulation.*—In this connexion nothing is to be said.

(*e*) *Respiration.*—Apparently all living things breathe. That which one is able to say of these lowly-organised beings can be said probably of all other plants and of all animals. Work implies waste. Waste implies decay. Decay is a form of combustion. Combustion is union with oxygen. Hence, when an organism is alive, it is constantly wasting, therefore constantly burning, therefore constantly oxidising. Now the products of this oxidation are injurious to the living body. They are usually carbon dioxide, or carbonic acid, $C O^2$, and steam, $H^2 O$. These must be got rid of from the body. This elimination of the gaseous products of decay is effected by respiration. At the same time, the necessary oxygen for this combustion has to be taken in, and this also is effected by respiration. So that, in full, respiration is the taking in of oxygen necessary for the combustion of the working tissues of the living body, and the elimination of the gaseous products of that combustion. In these low beings the respiratory organs are the whole body surface. No special part is yet devoted to the function of breathing. By the whole surface oxygen is taken in and carbonic acid given out. And here it will be well to pause for a moment and call the attention of the student to a great principle.

The lower we descend in our study of living things, the more do we find every function performed indifferently by every part. Nothing is specialised. The whole body feeds, breathes, reproduces. But as we ascend we see certain parts taking upon themselves certain definite functions. One part of the body becomes devoted to digestion, another to breathing; and the higher we ascend the more complex is this "physiological division of labor." So that, in the highest plants and animals, every function and every division of every function has its own special region of the body set apart for its performance. The verbal statement of this principle is known as the law of Von Bär.

(*f*) *Secretion.* (*g*) *Nervous System.* (*h*) *Sense Organs.* There is nothing to be studied under these.

(*i*) *Motor Organs.*—The student must be on his guard against a movement noticeable in these beings that he will be apt to regard as due to life. He will see a vibratory motion occurring in these small bodies, a movement of oscillation, the excessively minute particles of matter swaying backwards and forwards, or from right to left, without any absolute change of position. This, however, is not a motion of transference from one part of the fluid under the microscope to another. It is rather like the swaying of a pendulum backwards and forwards. This movement is to be seen whenever any very small particles of matter, living or dead, are suspended in a liquid. Very finely-divided charcoal or gamboge would present exactly the same movements if placed in water. Some of the Bacteria only show this motion, and then are said to be in the still stage. As in this condition they are usually surrounded by a quantity of jelly-like material, this stage is known as the zooglœa stage. But very often these organisms are in an actively mobile condition, and undergo movements of translation from place to place. The cause of these movements is in most cases not known. It is possible they may result from the general contractility of protoplasm referred to on p. 11. But in Spirillum volutans at each end a cilium or long fine hair-like process has been seen, and by the movement of the cilium that of the Spirillum as a whole is effected. Vibrio has apparently a wriggling motion. This is really due to Vibrio having a zigzag arrangement of its joints, and also a rotation upon its own axis. Hence, just as with the turning of a corkscrew on its own axis, there results the appearance of undulatory motion, even when there is no actual change of place. Bacillus is always free, and has not been seen in the still condition.

(*k*) *Reproduction.*—Reproduction in living things is either asexual when only one individual is concerned and sex plays no part, or sexual where the two opposite sexes are concerned. The former is called agamogenesis (α=without, γαμος= marriage, γενεσις = reproduction). The latter, gamogenesis. Only the asexual or agamogenetic method is known in connexion with those low forms of living things. The particular method encountered here is division or technically, fission (*findo*=I split). Certain divisions of the Bacterium undergo transverse division. A cytod is divided into two by an ingrowth of its wall, and the cytods thus formed last a longer time, and can resist injurious agencies more effectually than their fellows. By such division a Bacterium becomes two Bacteria. Bacillus also produces spores, *i.e.*, rounded structures that are thrown off from the parent and developed into a new being.

(*l*) *Development.*—As the act of reproduction produces at once a being of the same nature as the parent form, nothing can be said under this head.

(*m*) *Classification.*—The chief terms used in classification are as follows. The order in which they are now placed should be observed rigidly by the student. In our artificial but convenient way, we regard everything in the universe as either mineral, vegetable or animal. Hence the talk as to the three kingdoms of nature. In an equally arbitrary way we regard each kingdom as divided into sub-kingdoms (*sub* = under). Sub-kingdoms, again, contain classes. Each class is made up of orders. An order has genera (*genus* = kind). A genus consists of species. Hence in classifying Bacteria we say its food is inorganic, therefore it belongs to the kingdom Vegetabilia. It is a flowerless plant, without stamens and carpels; therefore it belongs to the sub-kingdom Cryptogamia (κρυπτος=hidden, γαμος=marriage). There is no distinction of axis and appendages, as in the stem and leaves of a tree; therefore it is of the group Thallophyta (θαλλος = a sprout, φυτον =plant). It is without green color matter; therefore of the class Fungi. Gamogenesis unknown, fission the only form of agamogenesis; therefore of the order Schizomycetes (σχιζω = I split, μυκος = fungus). Genus Bacterium, or Vibrio, or Bacillus, etc.

PRACTICAL WORK.—(1) Observe Brownian or molecular movement in gamboge or charcoal suspended in water.

doplast is brought into far more distinct view, the granules clearing away.

(5) Effect of temperature. The limits within which the white blood corpuscles of man appear to be active are 0° to 48° C. At a temperature as low as 0° they cease to move. At a temperature as high as 48° they are still. They thrive best at a temperature of 35°, which is that of the human blood.

(*b*) *Digestion.*—It is not yet clear whether the white blood corpuscle of man can take in food. But it is certain that those of the frog, after removal from the body, can be kept alive in the watery matter of the blood that is known as serum, and will in this condition take in finely divided matters, such as indigo, by absorption at the general surface.

(*c*) — (*d*) —

(*e*) *Respiration.*—It is impossible to say with certainty whether white blood corpuscles take in oxygen and give out carbon dioxide. They are alive, they are at work, they undergo decay. It may be therefore that such interchange of gases does take place. If it takes place the general surface must be the agency by which it is effected ; and in the white blood corpuscles of some animals under certain conditions appear contractile vesicles, like those of Amœba (see p. 21).

(*f*) — (*g*) — (*h*) —

(*i*) *Motor Organs.*—White blood corpuscles move. If one is carefully watched under the microscope, the student will observe that its shape is not constant. It undergoes slow alterations of form. Spherical at first, it protrudes a portion here, or another portion there, and assumes very diverse forms. These odd-looking protrusions, which are much more marked in the Amœba, are named pseudopodia (ψευδος = false, πουσ = foot).

(*k*) — (*l*) —

Practical Work.—(1) Draw white blood corpuscle and compare with red. (2) Draw one at intervals of thirty seconds; note change of shape. (3) Stain with iodine. (4) Stain with magenta. (5) Treat with acetic acid.

III. Amœba (αμειβω = I change). (*a*) *Structure.* (1) Occurrence. Amœbæ may be found in sea water and in fresh, in stagnant water, in mud, in damp earth. They may be obtained by exposing a piece of raw meat covered with a little water to the sunlight until all the water has nearly evaporated. They *may* then be found in the small quantity of water left, or by mincing very small portions of the surface of the meat with water. I write *may* in each case. Amœbæ are very uncertain beings, and we may go for a long time without meeting with any, and at other times have a rich supply. When these fail the student, the white blood corpuscles will serve very well as a make-shift, and they can always be obtained without difficulty. It is possible that some Amœbæ at least are only stages in the life-history of other organisms.

(2) Size. Very various; average diameter ·5 m.m. But it must be remembered that the different diameters of an Amœba are not always the same length. It may be at times much broader or longer in one direction than in another.

(3) General structure. Amœba is another irregular mass of protoplasm; but the protoplasm is to some extent differentiated, for nearer the centre of the Amœba it is more granular and more fluid than it is nearer the circumference. Hence names are given to the inner more granular, more fluid part, and to the outer less granular and more solid part. The former is called endosarc (*ενδον* = within, *σαρξ* = flesh). The latter is called ectosarc (*εκτον* = without). Yet Amœba is without a distinct wall or membrane. Its ectosarc is only a filmy rather more condensed part of the protoplasm of which the Amœba is made up. Within the endosarc is a more condensed part of the protoplasm, the nucleus or endoplast. At times within this the student may recognise a rounded granule, the nucleolus or endoplastule (*ula* = a diminutive ending).

(4) Forms of Amœbæ. Some Amœbæ have shell-like coverings. At times Amœbæ become surrounded by a sac not unlike the gelatinous investment seen in the still or zooglœa stage of Bacteria. Then they are said to be encysted. Lastly, another special form of this organism is occasionally seen, in which the distinction between ecto- and endosarc is but little marked, and the granular structure is not so evident (Amœba radiosa).

(*b*) *Digestion.*—The food of the Amœba is mostly vegetable. Low, *minute* forms of Algæ, water-plants low in the scale of vegetable life, are the staple comestible. These are taken in by a remarkable mechanism. If a particle of food is near an Amœba that part of the body of the latter which is nearest to the former is protruded as a pseudopodium (see page 21). The food-particle is touched by the protruded pseudopodium, adheres to it, and as the pseudopodium shortens and is withdrawn into the body of the Amœba, once again the food piece goes with it, and is drawn slowly into the endosarc. There is no mouth. There is not even a defined region that is to serve always as the temporary mouth. Any part of the body may be pushed out, and may seize food. This latter, once within the endosarc, passes slowly through the body of protoplasm, growing smaller and smaller; and after a while such portion of it as is not used by the Amœba is extruded at an indefinite point on the general surface of the body. It will be noticed that here is an advance on the ingestion of food by Bacteria. For in these last all the surface is concerned. But in the Amœba only a part of the surface is concerned in the taking in of any special food-piece. This part may be at any region. There is a clear advance in differentiation.

Amœba gets its organic food-stuff ready made. The tiny vegetable things it eats have beforehand fashioned out of mineral things an organic food-stuff, to be devoured in its turn by our Amœba. Now, the Bacteria can make their protoplasm out of mineral matter. Whether we, therefore, consider the nature of the food or the manner of taking it into the body, Amœbæ present a very marked advance upon Bacteria.

(*c*) *Absorption.*—Here also is a slight advance. In Bacteria we saw this function blended with that of digestion. But here, after the food has been digested, and whilst it is passing through the protoplasm or endosarc of the Amœba, the endosarc that intermediately surrounds the food-particle as it goes on its way must absorb nutritious parts and transmit them to the distant regions of the protoplasm. Thus even here, far down in the animal kingdom, occurs a simple, rudimentary but distinct act of absorption.

(*d*) —

(*e*) *Respiration.*—All that has been said as to the breathing of Bacterium applies here; and, indeed, as far as general principles of work, waste, decay, combustion, oxidation, in-taking of oxygen, out-giving of carbon dioxide, applies to other living things. But whilst Bacterium only breathed by its general surface, Amœba has a special organ for respiration. If the student watches an Amœba carefully for a while, he will presently see in the ectosarc region of its body a contraction and expansion occurring consecutively, as if a round window were opening and shutting in steady succession. Now there is a clear round space in the ectosarc; and now the space is lessening and lessening until it is a mere speck, and at last has disappeared altogether. Presently, at exactly the same spot, the mere speck will reappear and gradually enlarge until it is a clear round space once more. This space contracting and expanding is called the contractile vesicle. As it contracts, it would seem as if lines radiated from it into the surrounding sarcode or protoplasm. This much is certain. That which follows is not so assured. But probably this system of a central space and of canals possibly radiating thence into the protoplasm around is full of water that has air dissolved in it. And probably the system communicates with the exterior, so that the water can be changed. These probabilities are based on the knowledge of certain facts known in connexion with kindred structures in higher animals. If, then, we have here a pulsating central vesicle with radiating spaces passing thence, and if the whole system contains water holding air in solution, it is possible that thus oxygen is given up to the living active protoplasm into the midst of which the water is pumped, and that the carbon dioxide, that is the chief product of its waste is removed thence. It is on these grounds that the contractile vesicle is regarded as respiratory. Sometimes this structure appears to consist of two or more vesicles that contract as the canals radiating from them expand.

(*f*) — (*g*) — (*h*) —

(*i*) *Motor Organs.*—Pseudopodia act as motor organs, for if one of them is protruded from some region of the body of the Amœba, it may be fixed at its distal end, *i.e.*, at the end remote from the Amœban body, and then the whole of the rest of that body can be drawn up to the fixed part. Thus a crude sort of locomotion may be effected. The pseudopodia are at first wholly of ectosarc. After they have been extruded for a little while the endosarc flows into the extension of the outer protoplasm. It is from the numerous changes of form resulting from these extrusions and retractions that the Amœba takes its name of Proteus Animalcule, as Proteus was the shepherd of Neptune, and much hunted unfortunate that he was, found it necessary to assume manifold shapes for purpose of disguise.

In some Amœbæ the pseudopodia are confined to one region of the body of the Amœba.

(*k*) *Reproduction.*—Only agamogenesis is known positively. The special form of asexual reproduction that appears to be customary is fission or splitting. One Amœba is divided into two or more small pieces. Sometimes this division is preceded by encystation, and the Amœba first surrounds itself with a gelatinous envelope, and then splits up.

(*l*) *Development.*—The same remark applies here as under Bacteria.

(*m*) *Classification.*—As Amœba feeds on organic things, it belongs to the kingdom Animalia. As it is not made up of two or more cells, it belongs to the sub-kingdom Protozoa (πρωτος = first, ζωον = animal). As it has pseudopodia, it is of the class Rhizopoda (ριζα = root, πους = foot). As its pseudopodium is broad, it is a member of the order Lobosa. Genus Amœba.

PRACTICAL WORK.—(1) Draw an Amœba. (2) Mark carefully the endoplast and contractile vesicles. (3) Stain with iodine. (4) Stain with magenta. (5) Draw one with pseudopodia extruded. (6) Amœba encysted. (7) One with food particles in it. (8) Treat with acetic acid.

CHAPTER IV.

IV. YEAST.

(*a*) *Structure.*—(1) Occurrence. The ordinary brown powdery yeast is easily obtained at a baker's. It will excite the promotion of fermentation in bodies containing sugar, and probably whenever that process occurs in sugar-containing fluids or solids yeast is at work. Thus a species of yeast (Saccharomyces ellipsoideus) is met with on the surface of grapes and other fruits, and causes the grape juice to ferment in the making of wine. Ordinary yeast (S. cerevisiæ), if placed in a liquid holding sugar in solution, would induce fermentation. During part of the fermentation alcohol, $C^2 H^6 O$, and carbon dioxide, CO^2, are formed as the chief products. Glycerine, $C^3 H^8 O^3$, and succinic acid $C^6 H^4 O^6$ are also found in small quantities, at the same time. To show that during fermentation carbon dioxide is formed, fit up a flask, containing sugar, water and yeast, with a perforated cork, through which passes a delivery tube bent twice at right angles. Let the other end of this delivery tube pass through a second perforated cork down to nearly the bottom of a second flask containing clear lime-water. This second flask should have a second delivery tube, one end of which just passes through the cork of the second flask, and the other dips into a second supply of lime water in a third flask. Apply gentle heat to the first flask. Fermentation will begin, carbon dioxide will be evolved, and passing into the lime-water in the second flask, will form chalk (calcium carbonate, $Ca\ CO^3$). This will render the liquid cloudy, and then turbid. The object of the second supply of lime-water is to prevent that of the middle vessel from turning turbid from the carbon dioxide of the air. To show that alcohol is formed, place in a flask sugar, yeast, water. Through the cork of the flask pass a narrow glass tube open at each end. Gently warm the flask. When no more carbon dioxide appears to come off, place the flask in water, and raise the temperature of the water steadily. The alcohol that has been formed will distil over. Only select the first fifth of the fluid that distils over. Treat this distillate with potassium carbonate, $K^2 CO^3$. The distillate thus obtained will have the odor of alcohol, will be inflammable, and, treated with sulphuric acid and potassium anhydrochromate, $K^2 Cr^2 O^7$, will give the characteristic test for alcohol—viz., the red liquid becomes green, and a sickly odor of aldehyde is noticed.

(2) Size. Yeast plants have an average diameter of $\frac{1}{150}$ m.m.

(3) General structure. Each yeast plant is a cytod. It consists of a mass of protoplasm enclosed by a definite wall, and the protoplasm is, as usual, granular, semi-fluid, contractile. It consists of fat (a compound of C. H. O.) and what is called a proteid compound. Proteid is a general name given to certain complex organic compounds that, presenting much diversity of make, yet have a striking similarity that leads to the belief that there is a certain substance common to all these substances, but not yet isolated. The provisional name of protein is given. Chemical analysis shows that it consists in the yeast of the elements, carbon, hydrogen, oxygen, nitrogen, sulphur, phosphorus, potassium, magnesium, calcium, and that it is very closely allied to casein, the principle of cheese and milk. Casein has composition $C_{53.8}$, H_7, $O_{22.6}$, $N_{15.8}$, $S_{.1}$. In the granular protoplasm one can often see a space that is said to be filled with a clear fluid. This space is called a vacuole. It must not be confounded with an endoplast. The yeast has no endoplast. Hence it is not a true cell. It is only a cytod.

The wall is here very clearly marked. It is not a mere slightly differentiated part of the protoplasm, as is the ectosarc in Amœba. It is a definite envelope. The material of which it is made is closely allied to starch, and its name is cellulose. Cellulose is the usual material of which the walls of vegetable cells consist. Starch has the formula $C^6 H^{10} O^5$. Cellulose has the formula $(C^6 H^{10} O^5)^3$.

(4) Effect of re-agents. Treated with (α) iodine or (β) magenta, the protoplasmic contents are stained, *i.e.*, they acquire the yellow-brown color of the iodine or the reddish color of the magenta. The wall is either not affected at all

(the most general result), or, if the iodine does influence it, that which happens is that the cellulose of the wall turns blue. Starch and iodine always give a blue tint. Pure cellulose gives a like reaction. But cellulose, even in the yeast, is rarely pure, and hence with iodine alone this color reaction rarely occurs. A drop of very weak sulphuric acid applied to the yeast before the application of the iodine will often clean and purify the cellulose of the wall, so as to give the possibility of the iodine reaction. (γ) Potash solution dissolves out the protoplasmic contents, and leaves the wall as an empty sac.

(5) Effect of temperature. 35° is the best temperature. 100° kills yeast.

(*b*) *Digestion.*—Nature of food. Yeast thrives in any solution containing sugar. Pasteur's solution with sugar is a habitat in which the plant thrives well. The student will find the composition of Pasteur's fluid given, *minus* sugar, on page 12. To the salts and water in the quantities given on page 12, 75 grams of sugar should be added. Clearly, then, if we consider the composition of Pasteur's fluid, yeast has the power of building up from things mainly inorganic its organic protoplasm. It is this property which makes us call it a plant, for plants, as in this case, generally feed on mineral matters, and make organic structures out of them; and animals, as in the case of Amœba, feed on organic matters, and make yet other organic matters out of these. Intermediate between plants and animals in this connexion rank the saprophytes, such as Bacteria, that feed on decaying organic matter, *i.e.*, the organic matter that is passing through stages of simplification back to the mineral kingdom again. But whilst higher plants than yeast, as we shall presently see, obtain their food in no other way than this, and are, in the main, dependent upon the mineral kingdom for nutriment, yeast may, and very often does, get its food after the saprophytic fashion. When yeast grows in fermenting fluids, it may be said to be feeding on organic matter in the transition state that ends in inorganic products of decay. Even in the laboratory it can be shown that yeast will live and feed in fluids other than Pasteur's. Thus, if we replace the ammonium tartrate of Pasteur's solution by ammonium nitrate, $H^4 N NO^3$, or if we use Meyer's pepsin solution, yeast thrives well. Now, in the former case we have simplified matters, replacing an organic tartrate by an inorganic nitrate, and the yeast is more plant-like than ever. But in the latter case we have made matters more complex, for pepsin is an organic substance of great complexity, being, indeed, the nitrogenous body met with in the gastric juice of animals; and when the yeast lives in this fluid, it is less of a plant and more of an animal than before. The exact composition of Meyer's solution is as follows :—

15 per cent solution of sugar-candy	20 c. c.
Potassium dihydrogen phosphate $KH^2 PO^4$	1 decigram.
Calcium phosphate $Ca^3 2PO^4$	1 ,,
Magnesium sulphate $Mg S O^4$	1 ,,
Pepsin	23 decigrams.

Finally, let it be remembered that yeast can digest its food without any help from light. It feeds in the dark. No ordinary plant can do this. The whole surface of the cellulose wall will take in the food.

(*c*) *Absorption.*—Merged with digestion (see page 13).

(*d*) —

(*e*) *Respiration.*—By the general surface. All that has been said as to the breathing of the Bacteria applies here. But I must add that yeast can breathe in solutions containing no free oxygen, and in that case it is possible that the oxygen necessary for respiration is obtained from the decomposing sugar.

(*f*) — (*g*) — (*h*) — (*i*) —

(*k*) *Reproduction.*—Agamogenesis only obtains. But of this two methods are known. (1) From the cytods, that is the yeast plants, lesser ones are constantly budding off. It is no unusual thing to see a large and a small cytod in connexion, and a little later to see the small one pinched off from the larger. This process is known as gemmation (*gemma* = a bud). (2) Sometimes a cytod will have its protoplasm divided generally into four little masses, all still enclosed within the first unaffected cellulose wall of the parent cytod. The protoplasm, in fact, separates itself into four little groups. After a while the enclosing wall ruptures, and the four masses of protoplasm, or plastids, are set free. Then each acquires a cellulose wall, and we have now four yeast plants that have sprung from the one original yeast plant. This process is badly called endogenous division (ενδον = within, γενναω = I produce). The name is bad, because it is not a case of cell-division that we have here. It is a case of free cell formation. The protoplasm is not divided into two, and then into four segments by infolding of the wall. Round four centres four protoplasmic masses aggregate, and the wall of the original yeast plant does not fold in and divide the protoplasm, as in true cell division (see page 15). The four masses that result from this asexual free cell formation, are known as ascospores (ασκος = a bag).

(*l*) *Development.*—The product of the act of reproduction is either a cytod or a plastid. In the former case no development is needed. The creature is already a yeast plant. In the latter it is only wanted as far as the formation of a cellulose wall is concerned.

(*m*) *Classification.*—As the food of the yeast may be mineral, it is placed in the kingdom Vegetabilia. As it is not a flowering plant, and has no stamens or carpels, it is of the kingdom Cryptogamia. As it has no distinction between axis and appendages it is of the group Thallophyta. Without green color matter, therefore of the class Fungi. Gamogenesis unknown; reproduction by gemmation or free cell formation, not by division; therefore order Saccharomycetes (*saccharum* = sugar). Genus, Saccharomyces or Torula. Species, cerevisiæ.

PRACTICAL WORK.—(1) Draw yeast plants. (2) Treat with iodine. (3) Treat with magenta. (4) Crush them under a cover glass. (6) Draw cases of gemmation. (7) Of free cell formation. (8) Prove evolution of carbon dioxide in fermentation. (9) Prove that fermentation produces alcohol.

CHAPTER V.

V. PROTOCOCCUS (πρωτος = first, κοκκος = cell).

(*a*) *Structure.*—(1) Occurrence. This low form of vegetable life may be found in rain-water. Hence the water in water-butts, the mud in gutters and on roofs, and the shallow pools left shining after summer showers, are the best places in which to hunt for Protococcus. If Protococcus itself cannot be obtained, the green growth on the trunks of trees will yield its next-door neighbor, Pleurococcus, and in puddles or on Alpine regions is found Hæmatococcus (ʽαιμα = blood), red in hue, and forming, in the latter, the red snow.

(2) Size. $\frac{1}{14}$ to $\frac{1}{400}$ m. m.

(3) General structure. Protococcus is either a cytod or a cell. Whichever of these it may be, (α) a viscid protoplasm will be enveloped by (β) a cell-wall. The protoplasm and the wall are as in yeast. The nature of the former is not quite so clearly ascertained as in Saccharomyces, but we may take it as approximately akin to that described on page 24. The wall is undoubtedly of cellulose. But in the protoplasm are structures not yet met with. Starch is there very often, and green, or red coloring matter always. (γ) Starch is granular. It has a chemical composition represented by the formula $C^{6} H^{10} O^{5}$. In the higher plants its granules are of an oval form with many concentric lines. A full description of starch will be found later on. It is purposely postponed now because the nature of this starch is not as clearly made out as is that of the starch met with in the flowering plants. Probably in Protococcus the starch is distributed within the color-granules next mentioned, in the form of very minute granules. (δ) Color matters. Here in Protococcus we find for the first time green or red color-matter. This color-matter is granular, or is

diffused through the protoplasm. It is known as chlorophyll (χλωρος = green, φυλλον = leaf). This color-matter, which is normally green, as in the green of leaves, may by a slight modification become red or yellowish, and both the green and the red modifications are present in Protococcus. It consists of carbon, hydrogen, oxygen, and nitrogen. Sometimes the whole cytod or cell is green. Sometimes the whole cytod or cell is reddish. Sometimes the two colors are mixed. (ε) Vacuoles can be seen. (ζ) An endoplast may or may not be present. If it is not, Protococcus is a cytod. If it is present, Protococcus is a cell. So that here we have a being that is in an intermediate stage between the cytod and the cell. It is at times one, and at times the other. After Protococcus we shall never meet with an organism that is a cytod in our studies. Everything will be either a cell or made up of cells.

(4) Effect of re-agents. Plus iodine or magenta, the protoplasm only is stained. Plus sulphuric acid and then iodine, the cellulose wall turns blue. Plus potash, the protoplasm is dissolved, and the empty wall is left. Protococcus can be dried for a lengthy period, and yet recover.

(*b*) *Digestion.*—The food is mineral. That this is the case is conclusively shown by the fact that Protococcus lives in rain-water. Now in rain-water only carbon dioxide, salts of ammonium, and a trace of earthy salts from the ubiquitous dust, can be present. The mineral food-stuffs of Protococcus are the same as those of all plants, viz., carbon dioxide, CO^2, steam or water, $H^2 O$, ammonia, $H^3 N$. It will be noticed that these three important food-stuffs contain the four chemical elements, carbon, hydrogen, oxygen, nitrogen, and these are the four chief constituents of organic bodies in the different plants and animals. Out of the three binary compounds, carbon dioxide, water, ammonia, Protococcus can build up the ternary compounds, cellulose and starch, and the quaternary protoplasm or chlorophyll, and it is this power that makes the Protococcus a plant. Its food is mineral. It builds up out of that mineral food organic bodies. Unlike yeast, Protococcus must have light as helper. In the dark it cannot grow or even live. Under the action of sunlight the minute plant, like the larger vegetable, can seize on the carbon dioxide of the air, decompose this, retain the carbon, and give out the oxygen to the air again. An experiment to prove that Protococcus, in its feeding, gives up carbon dioxide, decomposes it, retains its carbon, and gives out its oxygen, is managed as follows. Arrange an inverted test-tube, filled with mercury, over mercury. Pass up into the tube above the mercury a little water containing Protococcus. Then pass up a little carbon dioxide. Expose the arrangement to sunlight for some hours. Then pass up some caustic potash. No absorption takes place, therefore no carbon dioxide is left. Pass up some pyrogallic acid. Absorption occurs, therefore oxygen is present. Therefore carbon dioxide has been decomposed, and oxygen left. The foodstuffs of the Protococcus are taken in at no special point, but by the whole of the general surface of the body.

(*c*) *Absorption* is merged with digestion.

(*d*) —

(*e*) *Respiration.*—All that has been said of Bacteria (page 13) is equally true here. But as the effect of Protococcus, as of other plants, on air is two-fold, and as a point of very great moment comes under notice here, I repeat briefly the essential facts to be remembered in connexion with respiration in plants and animals. A living being is at work. Work means waste. Waste means decay. Decay is combustion. Combustion is oxidation. Therefore Protococcus, as it works, wastes, decays, is burning and forming, as results of its oxidation, carbon dioxide and steam. These are to be got rid of, and this getting rid of the gaseous products of decay is effected by the general surface. Thus much for the respiration of Protococcus. But the effect of Protococcus upon the air is two-fold. We have seen that it takes food in the shape of carbon dioxide from the air. We now see that it also breathes the air. The two processes must be considered together, and this consideration of the two processes of feeding and breathing applies not only to *Protococcus, but to all plants.* (1) In breathing, Protococcus and other plants take in oxygen, and give out carbon dioxide. This process goes on constantly day and night, in sunlight and in darkness. (2) In feeding, Protococcus and other plants take in carbon dioxide, fix the carbon, and give out oxygen. This process goes on intermittently, by day not by night, in sunlight not in darkness.

Hence Protococcus and higher plants are both taking in oxygen and giving it out, are both taking in carbon dioxide and giving it out. The great question is which of these two processes is the more extensive. The answer to this is that the feeding process is much the more extensive. Truly it only goes on in the sunlight. But plants feed far more than they breathe; therefore the feeding process masks the breathing process. So that much more carbon dioxide is taken in and much more oxygen is given out, and the total effect of green plants is to remove carbon dioxide from and to supply oxygen to the air. It will be understood now why a green plant apparently only gives oxygen to the air. In the daytime it gives carbon dioxide, and it takes carbon dioxide away. The former process is a respiratory, the latter a digestive, one. But the latter is very much more extensive than the former. Hence plants work well side by side with animals whose main effect on the air is to receive oxygen, and replace it by carbon dioxide. A proper blending of the two forms is essential for the good life of both.

(*f*) — (*g*) — (*h*) —

(*i*) *Motor organs.*—The ordinary and best-known condition of Protococcus is a stationary one. But at times another state of the plant is seen. The round cells full of protoplasm change into round cells from whose wall the protoplasm is withdrawn at all points save two. At those points the protoplasm passes through the wall, as two fine threads that, protruding beyond the cellulose envelope, are plunged into the outside water. These prolongations are motile. They are cilia, and, lashing to and fro in the water, urge the Protococcus along at a considerable speed. Sometimes the cellulose wall vanishes altogether, and a naked mass of protoplasm, a plastid with two extensions of a slender motile nature, moves through the water. The motion of these cilia is so rapid that only the result of it can, as a rule, be seen. The movement of the cilia itself is indiscernable. But if the motile Protococcus is stained with iodine it dies, and the two fine filaments are rendered visible.

(*k*) *Reproduction.*—Agamogenesis only is known as yet. The form of this generally met with is division or fission. The round single cell is gradually divided into two by the ingrowth of the cellulose wall athwart the cell. A complete partition extends across the Protococcus, and the Protococcus becomes Protococci. The two thus formed by division of an older one are often seen still attached to one another, though sooner or later they separate. Gemmation or budding occurs occasionally.

(*l*) *Development.*—Here, again, the division of a Protococcus into similar ones does not admit of any history of development. But a curious point occurs in connexion with the two stages, stationary and motile, of Protococcus. Which is to be regarded as the primal form? Which is to be regarded as the after development? If we take the stationary Protococcus as the adult condition, fission is the method of reproduction, and two exactly similar Protococci result, and later each of these may become a motile Protococcus, which in its turn will go back to the still state. If we take the motile condition as the adult condition, rejuvenescence, or the formation of one cell from one cell, the cell formed being of an order other than that of the one whence it originates, is the method of reproduction. One dissimilar, stationary Protococcus results, and later this may divide into two or more of the same kind, and either itself or its progeny may pass into the motile stage. As the motile condition is so frequently met with in connexion with reproduction in the plants most nearly allied to Protococcus, I am inclined to regard the still Protococcus as the adult form; the motile, with its rejuvenescence, as representing the reproductive stage: to consider the first-formed still Protococcus as the result of reproduction, and all divisions of this as agamogenetic stages in its development. If ever the motile stage of Protococcus and its rejuvenescence are shown to be dependent on or connected with some form of gamogenesis, this suggestion will be of more value.

(*m*) *Classification.*—For reasons given above, Protococcus is of the kingdom Vegetabilia, of the sub-kingdom Cryptogamia, of the group Thallophyta. It has chlorophyll, and is therefore of the class Algæ. As no sexual reproduction is yet known, it belongs to the sub-class Protophyta (πρωτος = first, φυτον = plant). As it is green as a rule in color, the order is Phycochromaceæ (φυκος = Alga, χρωμος = color). The genus is Protococcus, and the species pluvialis (*pluvius* = rain).

Practical Work.—(1) Draw still Protococcus. (2) Stain with iodine. 3. Stain with magenta. 4. Treat with potash. 5. Make experiment as to its feeding, referred to on page 30. 6. Draw motile Protococcus. 7. Draw Protococcus undergoing division.

CHAPTER VI.

VI. INFUSORIA.—TYPES: BELL ANIMALCULE OR VORTICELLA AND PARAMŒCIUM.

(*a*) *Structure.*—(1) Occurrence. These microscopic animals are inhabitants, as a rule, of water. The water may be fresh or salt. They are found in ponds or in the sea. If any plants are allowed to remain for a while in water, that water will be found teeming with the organisms now to be considered. Hence the name Infusoria, as they occur in vegetable infusions. Some few are parasitic on animals. Thus in the intestine of the frog two large forms are met with. One of them is semilunar in shape, and is known as Nyctotherus; the other is pyriform or pear-shaped, and is known as Balantidium. These two Infusoria are free, *i.e.* are unattached to any definite basis. In the vegetable infusions a large number of Infusoria are also free, moving with great rapidity through the water. The two most common of those are Colpoda, a bean-shaped animal seen in hay infusions, and Paramœcium, of shape something like a slipper. This last is very common in water where plants have been living, and will be now described along with the bell-animalcule. The student often cannot obtain the latter, but can almost always get Paramœcium.

Of the fixed Infusoria, Vorticella, or the bell-animalcule, is the best known. The animal is fixed by a long stalk either to water plants or to the limbs of Crustacea. The stalk is simple, unbranched and contractile. Three other forms of Infusoria are met with in water in which Vorticella is likely to be present. These are very like Vorticella, but can be distinguished from it as follows. If the supporting stalk is branched and does not move, the animal is Epistylis. If it is branched and can move, we have Carchesium. If the stalk is very short, and the animal has a kind of cup or envelope into which it can be withdrawn, it is a Cothurnia. Any one of these may be met with, and the study of any one of them is practically the same as the study of Vorticella. Our description will now be made in reference to Paramœcium and Vorticella mainly.

(2) Size. All Infusoria are microscopic and their diameters vary greatly.

(3) General Structure. These beings are unicellular. A cell is a mass of protoplasm surrounded by a definite wall and enclosing a more solid portion known as nucleus or endoplast. In each Infusorium there is a wall, a mass of protoplasm, and an endoplast. The wall is more dense, more transparent than the rest of the animal, and is of formed material. It is called the cuticle (*cutis* = skin, *icula* = a diminutive). The protoplasmic contents consist on the exterior, *i.e.* in the region next to the cuticle, of a granular layer that is often marked by fine transverse lines or striæ. This is the cortical layer, sometimes called the contractile layer from its property of contractility, sometimes diaphane from its clearness. Within the cortical layer the protoplasm is softer and more fluid, and here it is called sarcode. So that from within outwards we have sarcode, cortical layer, cuticle.

Within the protoplasm is the nucleus or endoplast. This is always said to be in the cortical region, but it is certainly not there in Paramœcium, Colpoda, or the two Infusoria that are parasitic upon the frog. In Vorticella the endoplast is elongated, generally granular and of a horseshoe shape. Within this endoplast in most Infusoria, but not in Vorticella, is a yet more defined portion, called nucleolus or endoplastule. That which has been said is in the main true of all Infusoria. Vorticella itself is peculiar in one or two ways. In the first place, its body is cup-shaped, and the rim of the cup is thickened and everted or rolled outwards. This thickened, everted rim is called the peristome (περι = around, στωμα = mouth). Within the rim is a flattened part or disc. The relative position of peristome and disc will be understood if the student will imagine a moustache-cup in which the rim is the peristome, and the shelf to guard the moustache represents the disc. Only the disc extends nearly completely across the cup, and not only across a small part of it, as in the moustache-cup. The free edge of the disc is also thickened. Between the thick free edge of the disc, and the thick, everted edge of the peristome is a groove. At one place this groove leads into a canal, the vestibulum (antechamber). In the second place, Vorticella has its body supported on a stalk. This stalk consists of an outer sheath continuous with the cuticle of the body above, and a central axis continuous with the cortical layer.

(4) Effect of re-agents and temperature. (α) Plus iodine, everything is stained, except the cuticle, that is of formed material; the rest is protoplasmic. (β) With magenta similar results follow. With both these the endoplast comes out especially clearly. (γ) Potash. The protoplasmic contents disappear, but the cuticle remains. (δ) Osmic acid, $Os\,O^4$, is of great use in killing Infusoria, stopping their rapid movements, and enabling the student to see the structure of the animal with much greater distinctness. (ϵ) They can undergo desiccation for a considerable period, and revive on the application of moisture.

(*b*) *Digestion.*—Their food is organic, and chiefly of vegetable nature. They in almost all cases have a mouth, a distinct opening that leads to an œsophagus or gullet. This is the first time that we have encountered a definite mouth. Amœba takes in food at any point. Paramœcium and Vorticella only take it in at one point. The mouth leads into an œsophagus, but the œsophagus does not end in an intestinal canal. It ends abruptly in the sarcode of the interior of the body. It is open at the mouth extremity, but the opposite extremity is clogged up by sarcode. So that the food, after passing in at the mouth and down the œsophagus has to slowly make its way through sarcode, after the fashion that was general in Amœba. This, then, is the beginning of a digestive canal, but not the whole of one. At the lower end of the œsophagus the food is shaped into little pellets, each of which is surrounded by a layer of water, and these food vacuoles pushed on by the newer ones forming after them, make their way through the sarcode, often in a very definite course. As these pass through the sarcode, the digestive portions of them are taken up by the animal; and at last the indigestible residue is got rid of, not at a definite aperture in the body wall, but at a definite region; that is to say, there is no terminal aperture to the alimentary canal, but there is a clearly defined region, whereat the unused portions of the food are extruded. All this can be best seen in the Infusoria, by placing in the water some finely-divided carmine or indigo. The particles of these colored bodies will be taken in at the mouth, and may be watched in their passage through the body of the animal.

All the above is general. Turning to individual cases, it must be noticed that Vorticella has a mouth, not upon the surface of the body, but at the bottom of the vestibulum. Nyctotherus has a long curved œsophagus. Balantidium, the other frog-haunter, has a very short œsophagus, and in this animal the circulation of the food vacuoles is very plainly seen. They pass up one side of the body and down the other, always keeping well within the cortical layer. In Paramœcium, the tract through which they move is more limited. The circuit is completed in from $1\frac{1}{2}$ to 2 minutes, so that the speed of their motion is about $\frac{1}{360}$ m.m. to $\frac{1}{480}$ m.m. in one second. In Nyctotherus the passage of the food vesicles is so definite and so limited, they go so directly from mouth to anal region, that there is a direct foreshadowing of an alimentary canal.

(*c*) *Absorption.*—The layer of sarcode that is most immediately in contact with the circulating vacuoles must be the absorptive one, and must transmit that which it has absorbed to the more distant parts of the body remote from the food structure.

(*d*) *Circulation.*—Unless we are to regard the food vacuoles as in some sort blending the functions of digestion and of circulation in these beings, nothing is to be said under this head.

(*e*) *Respiration.*—Infusoria work, waste, decay, burn, oxidise. Oxygen must be taken in, carbon dioxide must be given out. That this is effected by the general surface is probable. But contractile vesicles, like those of Amœba, exist in these animals. They are in the cortical layer, and in the case of Vorticella the contractile vesicles are just below the disc. Paramœcium has two such vesicles. When the contractile vesicle expands its space extends as far as to the cuticle, and only that external layer is between the cavity of the vesicle and the exterior of the body. It is therefore possible that through the cuticle, either by a direct opening or by osmosis, the necessary water may be taken in, charged with fresh oxygen. The radiations from the contractile vesicle that appear when the latter organ contracts are very well marked, and extend into quite distant regions of the body. The system is, yet more clearly than in the Amœba, a respiratory one, and may be called a water-vascular system, for a water-vascular system here, and in yet higher animals, is a set of vessels (*vas* = vessel) containing air dissolved in water, contractile at one region, probably communicating with the exterior so as to admit of change of the contained fluid, and serving to introduce oxygen into, and to take up carbon dioxide from, the active parts of the body.

(*f*) — (*g*) —

(*h*) *Sense Organs.*—That Infusoria are sensitive to variations of light is shown by the way in which they congregate towards the side of the vessel whereon the light most falls, and they are exceedingly responsive to the stimulus of the electric shock, as will be seen when we deal with their movements. But no true sensory organs have hitherto been observed. Certain little color-spots noticeable in some Infusoria have been dignified with the name of eyes; but it is at least open to question whether this naming is not premature.

(*i*) *Motor Organs.*—The motor organs of Infusoria are all connected with the cortical or contractile layer. This layer is in some cases striated, and suggests muscular structures. This striation is least seen in Nyctotherus and Balantidium. But the chief organs of motion are minute, homogeneous, constantly active cilia, or fine hair-like processes that are visible on the exterior of the animals. These cilia are always in connexion with the contractile layer. They *seem* to spring from the cuticle; but, with careful examination, they may be traced at their bases into direct communication with the protoplasmic cortical region. Their motion is very rapid and determinate. It might be called even co-ordinated. They seem to work together. There is no trace of structure in them: no fibres, no lines. They are quite homogeneous throughout. Yet their motion is very marked, and it is affected by stimuli such as electricity, chloroform, and opium in the same way as are the nervous and muscular organs of higher animals. Sometimes these cilia are distributed over the whole of the body, as in the case of Paramœcium. Sometimes they are restricted to particular regions, as in the case of Vorticella, for in the latter the cilia are upon the edges of the peristome, or outer rim, and on the edge of the disc. Here they serve excellently to sweep food particles into the vestibule, at the lower end of which is the mouth. The movements of the body as a whole in this animal are unaffected by the cilia, except in the rare cases in which Vorticella detaches itself from its stalk, and for a time swims freely by the aid of cilia. Vorticella's chief movement is brought about by the agency of the stalk. That stalk is contractile. Its central axis is in direct continuity with the cortical layer of the body above, and is muscular. When under the influence of any stimulus, as a shock given to the glass upon which the animals are, or a very weak solution of acid, or a very weak electrical current, or often when minute observation can perceive no stimulus at all, the stalk contracts into a coil, the disc is drawn down into the cup, the edge of the peristome is curved inwards, and the body becomes globular, and crouched down close against the plant on which it is living. When all fear is over, the order of expansion is invariably, elongation of the stalk, eversion of the peristome, protrusion of the disc.

(*k*) *Reproduction.*—In Infusoria for the first time we meet with agamogenesis and gamogenesis. Asexual and sexual reproduction are seen here. All the known forms of agamogenesis present themselves in this class. Budding or gemmation, such as we saw in yeast, may occur. In Vorticella the gemmation is from the endoplast. That structure divides into several segments, and these are afterwards set free as new Vorticellæ. Splitting or fission is encountered. Most generally fission takes place at right angles to the longitudinal axis of the body. It is then called transverse fission. But in Vorticella the fission takes place along that longitudinal axis from above downwards, and this kind of fission is longitudinal. In both kinds of fission the endoplast divides first, and each of the two new beings formed has a fraction of the original endoplast. The third method of agamogenesis is encystation, which is the same as the free cell formation seen in yeast. In other words, the Infusorium becomes still, loses its cilia, is surrounded with a gelatinous wall, and the endoplast is generally greatly dilated. Colpoda, *e.g.*, undergoes this change, and then the substance of the animal breaks up into two, four, or more parts. The external cyst ruptures, and these parts are set free, and become the new Colpodæ. If the encystation takes place with an ordinary Vorticella, only one Vorticella results. Here there is no increase of number. One results from one, and this process ought to be called rejuvenescence. According to Everts, a Vorticella has been seen to become encysted, and then give rise to another genus of Infusoria, known as Trichodina grandinella. The Trichodina has then divided transversely, and each division has become a Vorticella. Again, a species of Infusorium known as Amphileptus has been seen to surround a stalked Vorticella, and then to become encysted upon the summit of the Vorticella stalk.

We may now sum up the various forms of asexual reproduction at present known in plants and animals. There is rejuvenescence where one cell forms one cell, as in the encystation of certain Vorticellæ, and the formation of a single Vorticella from a preceding individual. Fission, or division, where two are formed by the splitting of one. Gemmation, which is only a special case of division wherein the two bodies formed are of unequal size, while in ordinary fission they are of the same size. Free cell formation, in which the protoplasm within the cell wall divides, but the wall does not; so that within the unchanged old wall are formed several masses of protoplasm, and when the wall bursts these are set free. A tabular arrangement follows:

AGAMOGENESIS.	One formed from one = Rejuvenescence.		
	More than one formed from one.	The wall is infolded = Division.	Products equal in size = Fission.
			Products not equal in size = Gemmation.
		The wall not infolded: protoplasm within only divided = Free-cell formation.	

For fuller details upon this and all the phænomena of reproduction, see the author's "Biological Problems and Discoveries." (Freethought Publishing Co., 28, Stonecutter Street, E.C.)

A true sexual reproduction also occurs in Infusoria. It is effected by the coming together of two animals of the same species. But as these present no difference of sex as yet, and are apparently exactly alike, this coming together of two exactly similar cells is called "conjugation." Nevertheless, as two distinct individuals are concerned, though we cannot yet see any difference between them, this may be regarded as a sexual act, a case of gamogenesis.

Let us see how this occurs in Vorticellæ and Paramœcia. An ordinary Vorticella divides longitudinally again and again. Thus are produced many small Vorticellæ on a common stalk. These detach themselves, and each of them conjugates with a large ordinary Vorticella: that is to say, the small one attaches itself generally to the cuticle of a large one, and gradually the two completely fuse together.

Then the endoplasts break up. The segments of the endoplast may remain separate, or they may conjoin into one mass. If they remain separate some of them become germ-masses, whilst the rest rejoin and form a new endoplast. If they conjoin they form what is called a "Placenta." This placenta throws off germ-masses, and then lapses into the condition of an endoplast again. In either case the germ-masses give off parts of their substance, which escape as ciliated embryos, or young Vorticellæ, through a special opening in the cuticle.

In Paramœcia a yet more complex arrangement obtains. Conjugation here lasts four or five days. The Paramœcia conjoin in pairs by their mouth ends, and do not completely fuse together, as in Vorticellæ. Whilst they are thus attached to each other, the endoplast enlarges and forms small round bodies that we may call eggs. The endoplastule within the endoplast becomes oval, and marked with fine longitudinal stripes. Then it divides into two or four divisions, each of which contains many curved rods that we will call spermatozoa (σπερμα = seed, ζωον = animal). These appear to have the power of impregnating the eggs of the endoplast.

(*l*) *Development.*—In all cases of agamogenesis the being produced differs so little from the parent that no history of the development is needed. In the case of fission a basal circlet of cilia appears usually ere the two forms detach themselves one from the other. But in Paramœcia at least there are stages of development such as we have not yet encountered. The first germs probably result from the impregnation of the eggs formed in the endoplast by the spermatozoa formed in the endoplastules or rudimentary testes. Their membrane is brought into view by the action of acetic acid. Their contents are greyish purple, nearly homogeneous. Later, endoplast and contractile vesicle appear, and the embryo quits the interior of the mother, provided with extensions of its body that are knobbed at their free ends, and have also at that end suckers. By aid of these the young Paramœcia adhere to the body of their mother, and derive nutriment from her. Still later, they detach themselves from her, lose these knobbed sucker-bearing extensions, or tentacles, as they are called, acquire cilia and a mouth, and are Paramœcia of the parent type.

(*m*) *Classification.*—Kingdom, Animalia; sub-kingdom, Protozoa (page 22). As they have no pseudopodia and are cells, not plastids or cytods, and have cuticle, cortical layer, sarcode, they belong to the class Infusoria. As they have cilia, to the sub-class Ciliata. If the cilia are distributed all over the body as in Paramœcium, the order is Holotricha (ʽολος=whole, *θριξ* (*τριχος*)=hair). If the cilia are only found along a definite line of the body, as in Vorticella, the order is Peritricha (*περι*=around). Genera, Paramœcium and Vorticella. Species, P. bursaria is one of the commonest.

PRACTICAL WORK.—(1) Draw Paramœcium, marking especially the three regions of the body, the endoplast and positions of the two contractile vesicles. (2) Draw Vorticella expanded. (3) Draw Vorticella contracted. (4) Treat with iodine. (5) With magenta. (6) With acetic acid. (7) With osmic acid. (8) Draw specimen undergoing fission. (9) Draw an encysted Vorticella. (10) Conjugation.

CHAPTER VII.

VII. Moulds.—Types, Penicillium and Mucor.

Penicillium glaucum: Green Mould.

(*a*) *Structure.*—(1) Occurrence. This, the most frequently occurring form of mould, is found on jam, on bread, on old boots, or any form of leather.

(2) Size. The threads of which it is composed (v.i.) are of very varying length, and even their transverse diameter is not uniform. It is impossible to give the length. For the transverse diameter $\frac{1}{30}$ m.m. may be taken as an approximation.

(3) General structure. To the unaided eye Penicillium is a mass of interwoven threads covered with greenish dust. The greenish dust is a collection of the spores to be presently described. The interwoven mass of threads immersed in the jam, or the bread, or the leather, is the mycelium (μυκος = fungus). This mycelium is made up of many threads. Each thread is a hypha. Each hypha is formed by the conjoining of several cytods, end on with one another. The individual cytods are in no way essentially different from the cytods that are called yeast plants, save in that they are rectangular in shape, and of much greater length than breadth. Each has a cellulose wall. Each contains protoplasm, and in the protoplasm one or more vacuoles may occur. There is no endoplast. The protoplasm is, as usual, granular, but the layer of it that is next to the cellulose wall is less granular and more clear than the rest that is more internal. This outer layer of protoplasm that is in contact with the cellulose wall is known as the primordial utricle. It is named "primordial," because it was thought to be of the first importance. It is called "utricle," because this word means a bladder. So that in Penicillium, the cytod of yeast has become elongated, and in place of being oval is now rectangular. Then several of

these rectangular cytods have been joined one to another in a longitudinal row. Then the hyphæ, or threads, thus formed, have been interwoven together to form the mycelium or network of threads. The great advance here is in the fact that many cytods are conjoined, and the plant no longer consists of only one. The threads, or hyphæ, are often branched. Generally the branching is persistently into two divisions. This is called dichotomous branching (διχος = double, τομη = cutting). From the mycelium threads are given down into the substance upon which Penicillium is living. These are called the submerged hyphæ. Yet other threads are given up into the air, and these are called aërial hyphæ.

(4) Effect of re-agents. (α) With iodine, only the protoplasmic contents are stained. (β) With magenta, similar results follow. (γ) Potash dissolves out the protoplasm and leaves the empty cell wall. (δ) Penicillium can bear desiccation, in the same way as Bacteria.

(b) *Digestion.*—The food of Penicillium is as that of the yeast plant. It will grow very well in Pasteur's fluid, with or without sugar. Therefore it has the power of building up its protoplasm chiefly from inorganic things. But it will grow also in Pasteur's fluid that contains ammonium nitrate in place of the tartrate, or in Meyer's pepsin solution. As this mould is found living upon decaying and organic things, it would seem to be a saprophyte, and to be able to feed upon organic matters as they pass through the stages of decay towards that inorganic condition that is the ultimate fate of all living bodies.

If we consider how Penicillium takes in its food, whilst the general surface seems, as in the yeast, the main agent in ingestion, one is tempted to suggest that perhaps in this plant the submerged hyphæ, plunged as they are into the very depths of the decaying matter in which the mould grows, may be the special food absorbers, and that in this we may have a slight specialisation of function.

(c) *Absorption.*—Once more this is merged with the function of digestion. The very act of taking in food is an absorptive one. Not until high up in the animal kingdom shall we find these two functions clearly distinguished.

(d) *Circulation.*—For the first time we have, I think, indications of this function. In Penicillium, a number of cytods are placed end to end. Only some of them, those that form the submerged hyphæ, appear to be taking in food. From these, that which is taken in must be transferred to other parts of the mould. This must be effected by transference from cytod to cytod of the fluid resulting from digestion. There is no central mechanism, like the heart of animals, for urging this fluid from one part to another. Such change of position, if it actually occurs, must be brought about by osmosis. Probably the movements of fluids in plants generally depend, in the main, upon this principle. As we here meet it for the first time, it will be well to get as clear a conception of it as possible. Osmosis is the passage of fluids through membranes. Two great laws are known in regard to this osmosis. (1) It can only occur when both fluids adhere to the membrane. Thus, osmosis will not occur when mercury and water are upon opposite sides of a piece of wash-leather, because the mercury will not adhere to the wash-leather. (2) If the two fluids are of unequal density, the lighter one will pass through more rapidly than the heavier. Now, in all probability these principles apply in the case of Penicillium. For, consider any given cytod of this plant. It contains fluid; the next one to it contains fluid. The latter cytod is nearer the submerged hyphæ, let us suppose, than the former. Its contained fluid is therefore probably rarer or lighter than that of the cytod that is more remote from the submerged ingesting hyphæ. This is the more likely, as the longer a fluid has been in the Penicillium, the more likelihood has there been of its exposure to evaporation, and therefore the greater is the chance of its being increased in density. If then the one cytod contains a fluid, which, from its having been longer in the plant, and from its being farther away from the ingesting threads, is more dense than the fluid in an adjacent cytod, a greater flow will take place from the latter to the former, and a circulation of fluid will set in. Hence it is probable that such circulation from the lower hyphæ, through the mycelium to the higher, does take place.

(*e*) *Respiration.*—As in yeast or Protococcus. But, perhaps, in this function also there is some specialisation, for the submerged hyphæ and the ordinary mycelium can effect little in the way of breathing. But the aërial hyphæ protruded into the air, and in very contact with its oxygen, may serve, and I think must serve, especially for the performance of this function.

(*f*) — (*g*) — (*h*) — (*i*) —

(*k*) *Reproduction.*—Agamogenesis is the more frequent of the two methods. The aërial hyphæ, if they are not too near the circumference of the patch of mould, are found to give off many branches at their free ends. Each of these branches, by a series of transverse constrictions, is divided into many rounded bodies, like the beads in a necklace. The branch is a conidiophore (φερω = I carry). The rounded bodies are called conidia. These conidia are asexual reproductive organs. They make the powdery matter that one sees upon the surface of the mould, and may be looked upon as spores, or gemmæ, or buds, that may, as will be seen below, reproduce the whole Penicillium.

Another method that is agamogenetic has recently been discovered in Penicillium. Upon one of the aërial hyphæ a round body may be seen as large as a small pin's head. This is a mass of rounded cytods. But the microscope reveals running through this a number of hyphæ. These hyphæ bear little hollow sacs, within which are formed spores by free cell formation. Each of these hollow sacs borne by a hypha is an ascus (p. 47). The spores formed within it are ascospores. Later on, the whole of the rounded mass of rounded cytods vanishes, except the outermost wall. That remains, and within it are the hyphæ, bearing asci or spore-cases.

So that Penicillium forms conidia by a kind of gemmation, and ascospores by free-cell formation.

(*l*) *Development.*—Conidia, placed in Pasteur's fluid, with or without sugar, begin to develop. They bulge out at one or more points. From each of these points a hypha is developed. These hyphæ elongate and branch. Later on, transverse septa or partitions are formed. And in good time a mycelium of hyphæ is made. This sends downwards the submerged hyphæ, and upwards aërial ones that develop conidia.

(*m*) *Classification.*— Kingdom, Vegetabilia. Sub-kingdom, Cryptogamia. Group, Thallophyta. Without chlorophyll, therefore Class, Fungi. Mycelium of hyphæ made up of many cytods; spores in asci, therefore Order, Ascomycetes. Genus, Penicillium. Species, glaucum.

MUCOR MUCEDO.

(*a*) *Structure.*—(1) Occurrence. This mould is also likely to be found in similar situations to those in which Penicillium is encountered. But one of the best ways to obtain Mucor for work is to expose horse-dung for two or three days under a bell jar in a fairly warm room. Quantities of threads will develope on it, and these threads are those of Mucor.

(2) Size. The threads are longer and broader than are those of Penicillium.

(3) General structure. Here, as in Penicillium, we have a mycelium of hyphæ, with submerged and with aërial threads; but in the young Mucor, at least, this mycelium does not present transverse partitions. It is of one cell only at first, although later on partitions may be met with in older Mucors. But dichotomous branching does not occur, so that Penicillium and Mucor can be easily distinguished one from the other. The long cell-wall is, as before, in the main, at all events, of cellulose. The protoplasm is as of old, and is vacuolated.

(4) Effect of re-agents. These act upon Mucor as on Penicillium.

(*b*)—(*i*) Are all to be dismissed with the same treatment as they received in Penicillium, save that under (*d*) *Circulation* it should be noted that osmosis cannot so well come into play, as in all but old specimens no partitions exist, except at the regions where the hyphæ carry the spore-sacs (v.i.).

(*k*) *Reproduction.* Both agamogenesis and gamogenesis are known. (1) Agamogenesis. (*a*) Free-cell formation. The aërial hyphæ do not carry conidia, but they have quite large and palpable round heads. Each of these heads is an ascus, or sporangium, or spore case. The ascus is separated from the hypha that bears it by a transverse partition, that is usually bulged up into the ascus to form a small convex dome, the columella. The wall of the ascus is rich in crystals of calcium oxalate, $Ca\ C^2\ O^4$. Within it are formed by free-cell formation many spores. As these are formed by free-cell formation, not the whole of the protoplasm enters into them. That which is not used in the forming of the spores remains as an intermediate substance. Gradually the wall thins away, until only the crystals, or very little more than the crystals, are left. Now, the wall is very brittle, and a very slight touch will cause it to rupture. Thus the contained ascospores are exposed to the air and the water surrounding the Mucor. The intermediate substance swells and dissolves away. The wall of the ascus, after rupturing, falls away, though the basal supporting cell remains with the columella. The spores are set free.

(β) Gemmation. If Mucor is not allowed to grow at the surface of a sugary liquid, but is kept submerged, gemmation or budding is the method of reproduction that obtains. Coincident with this persistent gemmation, is, after the fashion with yeast, a fermentation, so that this stage is often named the Mucor Torula.

(2) Gamogenesis occurs in the form of conjugation. Two different threads, or two parts of the same thread approximate. Each gives out a process towards the other. The free ends of these processes dilate and then touch. Next, the protoplasm in each of these processes is cut off by a transverse partition from the great mass of protoplasm in the rest of the hypha with which the process is connected. So that now the two touching ends of the two processes are cut off from the two threads, or the two parts of the same thread, whence they took origin. The two partitions at the originally free ends of the processes, now vanish, so that the two masses of protoplasm in the two processes blend and form a body, the result of conjugation. This body is often badly called a zygospore ($\zeta v\gamma o\nu =$ a yoke). It is better called a zygosperm ($\sigma\pi\epsilon\rho\mu\alpha =$ a seed). It is clearly a product of sexual reproduction, though we do not know which is the male or which is the female parent, and it is wise to restrict the name "spore" to asexual results. This zygosperm has two coats, the outer dark exosporium, the inner colorless endosporium. Both have irregular elevations on their surface.

(*l*) *Development.*—(1) Of the ascospore. The ascospores are oval, and have exactly the same parts as a hypha, viz., a cellulose wall, primordial utricle, protoplasm, save that the wall is colored. Under favorable circumstances, as *e.g.*, if placed in Pasteur's solution, the oval spore becomes spheroidal, and sends out several extensions, each of which becomes a hypha. As I have said, no partitions or septa appear at first, so that Mucor is for some time unicellular.

After a time, from the centre of the mycelium thus formed, a vertical aërial hypha is given off. At the end of this is formed a dilatation, the sporangium. This is cut off from the hypha that carries it by a transverse partition, that curving upwards towards the cavity of the ascus, becomes the columella. Crystals of calcium oxalate appear in the walls of the spore case. By free cell formation the spores are formed, leaving the unchanged protoplasm as intermediate matter.

(2) Of the zygosperm. For a long time the zygosperm is at rest; at last it develops. Both its coats, the outer and the inner, burst, and a single process extrudes. Only one hypha is formed, and this is very short and unbranched. From this short unbranched hypha rises an aërial one, bearing a sporangium. From the ascospores in this, the ordinary Mucor is developed.

As the full history of Mucor may be summed up in the following stages, spore, mycelium, conjugation, zygosperm, single hypha, aërial hypha, sporangium, spore again; as, therefore, Mucor presents two methods of reproduction, the asexual by ascospores, and the sexual by zygosperms; and as the products of these two methods differ, being in the one case a mycelium, whose threads conjugate, and in the other a hypha, bearing a sporangium—the unfortunate phrase, "alternation of generations" is often used in regard to Mucor. But the alternation is not between generation and generation, if generation means gamogenesis. It is rather between generation and gemmation, *i.e.*, between a true sexual reproduction, and an asexual method. If we accept the definition of a biological individual, given by Professor Huxley as the whole series between one true gamogenetic act and the next, "alternation of generation" does not occur. The individual, though it passes through two or more stages, is one.

(*m*) *Classification.*—Kingdom, Vegetabilia. Sub-kingdom, Cryptogamia. Group, Thallophyta. Class, Fungi. As Mucor has spores formed in asci, and its sexual reproduction is conjugation, as also its mycelium is at first unicellular, it belongs to the order Zygomycetes. Genus, Mucor. Species, mucedo.

PRACTICAL WORK.—(1) Tease out mycelium of Penicillium. (2) Treat mycelium with iodine. (3) With magenta. (4) With potash. (5) Study aërial hyphæ. (6) Submerged hyphæ. (7) Conidia. (8) Conidia germinating. (9) Mucor mycelium. (10) Stain with iodine. (11) With magenta. (12) Treat with potash. (13) Study aërial hypha with ascus. (14) Columella after ascus is gone. (15) Ascospores. (16) Conjugation. (17) Zygosperm. (18) Germination of ascospore. (19) Of Zygosperm.

CHAPTER VIII.

VIII.—STONEWORTS.

Chara or Nitella.

(*a*) *Structure.*—(1) Occurrence. The two stoneworts are found in all parts of the world. They occur in ponds and in rivers. One of them, Nitella, only lives in soft waters. It will not thrive in water containing many salts in solution.

(2) Size. These plants grow in an entangled mass, and an individual may attain a length of three or four feet. In thickness, they are about the same diameter as a large needle.

(3) General structure. The stoneworts are wholly cellular. Every part of them is made up of cells. No fibres or vessels as yet appear; but instead of consisting of a single cell, as in Infusoria, or of a simple row of cells placed end on, as in Penicillium, we have here the cells grouped into distinct organs. A central axis, giving off side-pieces, is now visible. This central axis is the stem. The appendages it bears upon its sides are arranged in circles or whorls. These whorls are much crowded near the free extremity of the plant, and are at greater distances one from the other lower down. The level at which the central stem gives off a set of lateral appendages is called a node (*nodus*=knot). The length of stem between any two successive nodes is an internode (*inter* = between). Of the lateral appendages there are rhizoids, leaves and branches. The rhizoids (*ῥίζα* = root) are fine threads immersed in the water or the mud, and given off generally from the lower part of the stonewort. The leaves often bear small leaflets. The branches take origin in the angle between the leaf and the stem. As this angle between the leaf and the stem is known as the axilla (arm-pit), the branching is said to be axillary.

Turning to the consideration of the minute structure of the plant, we find that each internode is made up of one long central cell extending from a node below to a node above.

This is the medullary (*medulla* = pith) or internodal cell. In Nitella this cell is the whole of the internode. But in the more common Chara this central elongated cell is surrounded by several others, wound spirally round it, and called cortical cells. These investing cortical cells can be traced into direct continuity with the cells of the nodes. In fact, they are, as will be seen in the study of development, extensions of the nodal cells. From the node above they can be traced downwards, and from the node below they can be traced upwards, until they meet about the middle of the medullary cell. The line of the junction of the two sets is called the equator.

The node differs from the internode. It is a flat mass of rounded cells, not elongated along any particular diameter. The cells are spherical, so that the axis consists of a series of long internodal cells, each surrounded by cortical cells (in Chara), and with a flat mass of spherical cells interposed between each pair of internodes.

The rhizoids are simply rows of cells placed longitudinally. They resemble the hyphæ of Penicillium.

The leaves are of a like construction to the axis; but the end cell of a leaf is always long and pointed.

The branches are exactly like the main axis, or stem, in their histological structure.

Considering next the intimate structure of each cell, we find a cellulose outer wall investing protoplasm. Within the protoplasm is, when the cell is young, a large endoplast or nucleus, and one or more vacuoles are generally present. Later, the internal contents are watery, and like cell-sap; but the outer contents are still viscid, forming an internal lining to the cell-wall. This layer of persistent protoplasm is the primordial utricle, although it is not quite homologous with that of Protococcus. The endoplast becomes embedded in this primordial utricle, and in this same layer the green color-matters are placed. As this is the first time that we have met with this green color-matter in large quantities, I give a description of it now that will apply to the green color-matter throughout the vegetable kingdom. The green color is due to certain oval bodies called chlorophyll granules, or chlorophyll corpuscles. Each corpuscle consists of a colorless ground substance, through which the color-matter, true chlorophyll, is diffused. This colorless ground substance is specialised protoplasm. In addition to the green color-matter, starch is generally present. Sunlight is necessary for the formation of chlorophyll. The rays of low refrangibility are not the only ones that can induce the formation of chlorophyll. Even those of high refrangibility play some part in the making of this important substance. Alcohol will dissolve out the color-matter, leaving the ground substance untouched. In the stoneworts, the chlorophyll is disposed throughout the primordial utricle over all parts of the inner lining of the cellulose wall, save one band. This is left uncolored; so that a spiral, colorless line of some breadth can be made out, passing round the inner side of the wall, and bounded on both sides by a broad plain of coloring matter.

The terminal or end-bud needs a special account. If it is carefully sought for at the very end of a branch, or of the main axis, the end-bud will be found to have at its very extremity a hemispherical cell with the bulging convex part outwards. There is no vacuole in this cell, but an endoplast is present. Sometimes two endoplasts are seen, and that indicates that the end-cell is about to divide into two. Immediately beneath this terminal cell, and separated from it by a transverse partition (the chord of the hemisphere mentioned above) is a second cell, and below that a third, which is usually broken up into several smaller cells, by a number of longitudinal partitions. This is the most recent node, and below it will be found a longer, broader cell, that is an internodal one. This is succeeded, as we work from the apex of the branch backwards towards the main axis by a node, from the sides of which, possibly, little cellular eminences project that are to be the leaves, whilst from the same node cells are growing downwards over the next succeeding internodal cell, to form (in Chara) the cortical layer.

Finally, in this connexion, the distinctions between Chara and Nitella are as follows. Chara has a quantity of crystals of calcium carbonate Ca CO^3 studding the exterior of its cells. Nitella has none. The cortical cells, so often mentioned, are present in Chara, wanting in Nitella. A third mark is that in Chara only one branch springs from each whorl of leaves, whilst in Nitella two branches take origin from each *whorl of leaves.*

(4) Effect of re-agents. Iodine, magenta, potash act as upon the lower plants. Alcohol is of value, as it causes the primordial utricle to contract away from the cellulose wall, and so to become very distinctly visible. Alcohol also dissolves the color-matter out of the chlorophyll corpuscles

(*b*) *Digestion.*—(1) The food is mineral matter. Carbon dioxide from the air or dissolved in water, water itself, ammonia possibly, salts from the mud in which the rhizoids are plunged, these constitute the chief food of Chara and of Nitella.

(2) Ingestion. The rhizoids do but little work in the intaking of food. The general surface of the plant contributes largely to this labor. As the chief food is carbon dioxide, and as the stoneworts retain, or fix, the carbon of this gas, and evolve the oxygen, the process of feeding, or of assimilation, as it is often called, is a means of furnishing oxygen to the air dissolved in the water in which the plant lives, and of removing carbon dioxide thence.

(*c*) *Absorption* is not a process distinct from digestion in Chara, or, indeed, in any plant.

(*d*) *Circulation.*—(1) In the individual cells. If a stonewort is in active condition, and the temperature is not too high or too low (30° to 35° is best), a remarkable movement of protoplasm is visible. This movement of the protoplasm within the individual cells, is called cyclosis (κυκλος = circle). It was discovered by Corti. In young cells the protoplasm is quite still; but after the central part of the contents has become watery, and like cell-sap, the inner layer of the primordial utricle or persistent protoplasm rotates. The outer part of this primordial utricle, next to the cellulose wall, and having embedded within it chlorophyll corpuscles, and sometimes the endoplast, does not move. The student must focus through this, and observe the inner layer of the primordial utricle next to the watery central region. Hence, when the chlorophyll corpuscles are in good view, cyclosis will not be visible. The movement is tolerably rapid, and the protoplasm can be seen to pass round and round the cell. One current of it will be moving up one long side of the cell, whilst another is moving down the other long side. The colorless band, where no chlorophyll is, shows no movement, and is, indeed, the boundary between *the two parts of* the current, the one ascending, the other descending. If the endoplast is free within the cell, it is carried along by the stream of protoplasm. The cells in the end-bud, or one of the manubria, are excellent ones in which to study the cyclosis. This phænomenon is to be seen in other plants, as *e.g.*, in the leaf of the canal weed, or Anacharis, the hairs upon the stamens of the spider-wort or Tradescantia, and the stinging hairs of the nettle (Urtica).

(2) General circulation. In addition to cyclosis, a movement of fluid from part to part of the plant occurs. Food taken in by the rhizoids, or by the upper part, *e.g.*, of the plant, must be transmitted to other regions, and the watery, sap-like nature of the central part of the cell-contents points to the same conclusion. An osmotic action is probably constantly at work. The upper regions of the plant may also be evaporating to some extent, and probably a flow of fluid takes place from cell to cell. This may be regarded as a rudimentary circulation.

(*e*) *Respiration.*—The remarks made upon Protococcus, under this head, might be repeated here. The general surface is the place at which oxygen is taken in, and carbon dioxide given out, in the process of respiration.

(*f*) — (*i*) —

(*k*) *Reproduction.*—(1) Agamogenesis. Small masses of cells are sometimes detached from Chara or Nitella. They come off from the axils of the leaves at the points whence the branches usually spring. These masses of cells, at first axillary, afterwards detached, fall to the ground, and develop into complete plants. They are therefore like bulbs, or buds, and may be called gemmæ.

(2) Gamogenesis. For the first time we have clearly marked sexes in our study of living things. Both sexes are present in the same individual, *i.e.*, the stoneworts are hermaphrodite (Ἑρμης = Mercury, Αφροδιτη = Venus) or better, are bisexual. A bisexual living thing is one wherein the two sexes are conjoined in the same individual. In the stoneworts the reproductive organs are met with in connexion with the nodes. The female is usually axillary; the male is usually sub-axillary, or a little below the whorl of leaves and branches.

(*a*) The female organ. ♀ This is the sign of Venus, and is often used to denote that the animal or plant named is female. When ready for impregnation this organ is

Nitella, is the pro-embryo (*pro* = before). Presently, a cell some little distance from the free end of the hypha gives off small buds that develop into leaves, but the leaves are not in a regular whorl. Among these leaves a bud exactly like one of the terminal buds of the adult plant (page 53) appears, and this develops into the new plant. The succession, therefore, is as follows: Oosphere, oosperm, hypha, first rhizoid, pro-embryo, cell-budding, leaves, primal bud, Chara. The development of this primal bud proceeds upon the same model as that described on page 53, save that, at first, only leaves and rhizoids are formed, and later the whorls of branches appear. The end cell always divides across the longitudinal axis. The leaves are always formed by the multiplication and outgrowth of nodal cells, and they grow from the base, the end cell of the leaf soon attaining its full size and never dividing. The branches developed from nodal cells in the axils of leaves have the ordinary terminal cell, and develop after the fashion of the axis.

(*m*) *Classification.*—Kingdom, Vegetabilia. Sub-kingdom, Cryptogamia. As they have axis and appendages, these plants belong to a group other than any we have yet seen. This is the Cormophyta (κορμος = stem).[1] Possessing large male organs, the class is Characeæ. No division of this into orders is made. The two genera are Chara and Nitella. Species, C. fragilis, N. flexilis.

PRACTICAL WORK.—(1) Naked eye. (*a*) Draw parts of the plant as a whole, showing axis, rhizoids, leaves, branches, reproductive organs (if present). (2) Low power of microscope. (α) Rhizoid. (β) Internode. (γ) Transverse section of node. (δ) Leaf. (ε) Archegonium. (ζ) Antheridium. (3) High power. (α) Vertical section of internode. (β) Cyclosis. (γ) Terminal bud. (δ) Antheridium teased out. (ε) Archegonium teased out. (ζ) Development of oosphere. (η) Pro-embryo.

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[1] I place the stoneworts among the Cormophyta as that position seems theirs by right of structure. Prantl and other Botanists place them among the Algæ (see Protococcus).

CHAPTER IX.

IX. Fresh-Water Polyp.

(*a*) *Structure.*—(1) Occurrence. Upon the stems of fresh-water plants. The little rootlets of the duckweed or Lemna are a frequent habitat of the Hydra, but it may be found upon any vegetable matters in still waters.

(2) Size. We are now out of the range of microscopic beings, for Hydra is visible to the unaided eye. Its normal length is from 6·25 m.m. to 12·5 m.m. When its tentacles are fully extended, a much greater length than this is attained.

(3) General structure. The fresh-water polyp is a bag-like animal of cylindrical or conical form. It is fixed by its base to the plant upon which it is placed, and that base is the hydrarhiza. It is, in the main, a cellular animal. Almost every part of it is made up of cells, though we shall find certain fibres occurring for the first time. But these cells are now arranged in layers or tissues. For the walls of the bag are not simple. They are double. The internal cavity is bounded on all sides, except at the summit, by a double wall. The two layers of this wall are called respectively the ectoderm (outer) and the endoderm (inner). Each of these body-layers is made up of cells. Those of the ectoderm are of two different sizes. Some are long and conical in shape, with the broad end turned outwards. Some are smaller and rounded in shape. These latter lie between their larger fellows. The cells of the ectoderm, whether large or small, are not very well marked off or distinct one from the other On the other hand, the cells of the endoderm are well-marked and are all of one size. They often contain chlorophyll, and that color-matter is never seen in the ectoderm. As each individual cell of the ectoderm and of the endoderm is nucleated and contractile,

to call the Hydra a collection of Amœbæ is no exaggeration.

(4) Effect of reagents. Iodine, magenta, potash act upon the individual amœboid cells as they act upon cells generally. The two former stain the protoplasmic contents, and do not affect the exterior. The latter dissolves out the protoplasm, but does not affect the wall. Magenta especially has the effect of causing the thread-cells (v. i.) to discharge their contents.

(*b*) *Digestion* (1) The food. Organic, consisting for the most part of small Crustacea, such as Daphne, the water-flea.

(2) The food is taken in at the mouth, an opening at the base of and between the long feelers or tentacles that are attached to the free end of the body. This central mouth, at the distal end of the body, leads into a single cavity. This cavity is at once the body cavity and the digestive cavity. As we shall often have occasion to use these two phrases, and as they are very important ones, I pause for a moment upon them here. If the body of one of the higher animals is opened, a cavity is found containing many organs, such as heart, liver, kidneys. This cavity is the general cavity of the body, or somatic cavity (σωμα = body), or perivisceral (περι = around, *viscera* = internal organs). It is traversed in the higher animals by a tube, more or less convoluted, that runs from one end of the body to the other, and is closed save at its two extremities. This is the digestive tube or gastric cavity (γαστηρ = stomach). Now, in the higher animals these two cavities are distinct, and the one, the digestive, runs through the other, the body-cavity. But in Hydra the two cavities are blended together. The single cavity within the two body-layers, the one cavity into which the mouth opens, is at the same time body-cavity and digestive cavity. Here, once again, the law of Von Bär is presented to us. The food then passes into this bag lined with endoderm, and there undergoes digestion. Whether the cells of the endoderm secrete any digestive fluid cannot be said, but assuredly the food changes greatly after its reception within the body. The indigestible residues must be extruded at the mouth. So that this opening serves at once as mouth and anus.

(*c*) *Absorption.*—Here the functions of digestion and absorption are to some extent separated. The absorption of digested food must be accomplished by means of the endoderm. The ectoderm is never in contact with the food. Therefore, a definite layer has here a definite function; that of taking up the digested food and then transmitting it to the outer layer of the body-wall.

(*d*) *Circulation.*—True circulation can only occur when a fluid exists that can be called sap or blood. Blood in the animal must have two qualifications. One is an anatomical, the other a physiological one. As to its anatomy, or structure, blood must be corpusculated. As to its physiology, it must be nutritive. The name "blood" should only be applied to a fluid that contains corpuscles or definite solid bodies, that is nutritive and serves to restore wasted tissue. Now, though in the Hydra no heart and no blood-vessels exist, yet the fluid within the cavity that is at once body and gastric is corpusculated. Under the microscope, the fluid in Hydra presents small, solid bodies, not altogether unlike the white blood corpuscles of higher animals. This fluid, then, we are permitted to regard as a rudimentary blood. It is called chylaqueous fluid, because it has some of the properties of chyle, or the product of digestion in higher animals, and because it is so largely watery. And the student, bearing in mind the law of Von Bär, will notice that this blood-fluid is at first in no definite vessels but is loose in the body-cavity, that is also the digestive cavity, so that this single sac within the two layers of the body-wall may be said to be not only somatic and gastric, but circulatory also. From this first appearance of blood in the animal kingdom, from this condition where the blood is floating freely in the one cavity, we may trace upwards every gradation of structure, until we find it confined within tubes that are almost, but never wholly, shut off from the body-cavity.

(*e*) *Respiration.*—There are no special organs. But the ectoderm is probably the respiratory layer. By it carbon dioxide is given out and oxygen is taken in.

(*f*) —

(*g*) *Nervous System.*—For the first time something definite can be said under this head. From the inner end of the conical cells of the ectoderm fibres are given off. They run up and down between the ectoderm and endoderm, and are known as Kleinenberg's fibres. First, let the reader notice that we have something more than mere cells; we have fibres, *i.e.*, extensions in a longitudinal direction. Second, let him see that we have at least the rudiments of a third layer of the body-wall interposed between the ectoderm and endoderm. For these Kleinenberg's fibres, although connected with the former, lie between the two layers, and constitute the rudiment of that important intermediate layer that we have fully developed in the higher animals, and that is called the mesoderm (μεσος = middle). Third, let him notice that these fibres, from their position and structure, are likely to act as communicators between different regions of the body. When he reflects upon the ease with which a stimulus affects the Hydra, he may be inclined to believe that here we have the first and simplest form of nerve structure.

(*h*) *Sense Organs.*—Here also, if we neglect the few words said under this head as to Infusoria, we have for the first time something definite to say.

(1) Kleinenberg's fibres are in their ultimate structure very like the curious bodies always encountered in the sense organs of higher animals, such as the olfactory cells, and the fibres of Corti in the ear. Though we cannot say positively that the fibres of Kleinenberg are sense organs, attention ought to be called to the resemblance between them and the essential elements of the sense organs in other animals.

(2) The tentacles. These seem to be tactile. They are extensions of the body wall, containing both ectoderm and endoderm, and the rudimentary mesoderm in the shape of Kleinenberg's fibres. They are hollow, and are richly supplied with the structures next to be mentioned. When they are fully extended, they have a curve downwards, so that the free ends often pass far beyond the hydrarhiza. Very slight stimuli will cause them to shorten. They are very sensitive.

(3) Thread-cells. These structures, technically known as nematocysts (νημα = thread, κυστος = cell), are very abundant in Hydra. They are met with all over the body, but especially upon the tentacles. Here they occur in little groups, or nematophores (φερω = I carry). Each of the thread-cells is an oval cell of the ectoderm, containing a

thread and a fluid that seems to be poisonous. Three chief forms present themselves. (α) With a long thread coiled many times spirally within the cell, and with three short sharp processes at the base. (β) The same, without the three radiating processes. (γ) As the last, but the thread is short. The application of magenta brings these threads out in great numbers.

(*i*) *Motor Organs.*—Sometimes the polyps float passively in water, when they have loosened their hydrarhizic hold. More frequently they move from one place to another by bending the body over and fixing the free ends of the tentacles whilst they detach the hydrarhiza. In turn the latter is brought over and into contact with the piece of plant upon which the animal is moving ; the tentacles are freed, and the Hydra comes right-end upwards again, after a temporary standing on its head. These slow and stately somersaults may be effected, as the contractions of the animal appear to be, by the fibres of Kleinenberg. Certainly these fibres would seem to be muscular as well as nervous. Nor is it matter for surprise that one and the same structure should combine the two functions of nervous and of muscular tissue. For, in the first place, the two functions are very closely allied; and, in the second place, we are prepared by the great generalisation of Von Bär to find the same tissue performing in the lower animals functions that in the higher are restricted to particular tissues. It must be remembered that the endoderm cells, none of which is connected with the Kleinenberg fibres, are often provided with a single cilium, and even when they are not thus armed they show amœboid movements.

(*k*) *Reproduction.*—(1) Agamogenesis. (α) Gemmation is very frequent. From any part of a Hydra a protrusion is formed. It is hollow, including both ectoderm and endoderm, and the cavity of it is in continuity with the somatic and digestive cavity of the parent. This protrusion elongating, its free end presently thins away, and we have a small Hydra with its mouth open into the circumambient water, but its central cavity in connexion with that of its parent. Later, by a constriction occurring at the base of this bud, the young one is thrown off. This is discontinuous gemmation. By this process many Hydræ may be budded off from one original form, and sometimes the secondary being has begun to bud off a tertiary one ere it quits the primary Hydra.

(β) The experiments of Trembley demonstrated that artificial fission or division of Hydra was possible. He split a Hydra into two by a vertical cut, and each half reformed its fellow. The like treatment in a transverse direction resulted in the upper half reforming the lower, and the lower half developing a mouth and tentacles. Even a small piece of the Hydra snipped off reconstructed the rest of the animal. This fission appears to occur at times naturally, without requiring the aid of an enthusiastic naturalist.

(2) Gamogenesis. In the summer time true sexual organs are formed. The Hydra, as might be expected from an animal so low in the scale, is bisexual. (♀) The female organ appearing near the hydrarhiza is a large colorless body in Hydra viridis. There are as many as eight such colorless bodies in some species. The one or the eight ovaries (*ovum* = egg), or egg-cases, is or are of ectoderm cells, principally of the smaller form. Within each is formed one egg. This consists, as do all the eggs of animals higher than Hydra, even up to man, of a central spot, distinct, round, called the germinal spot; a clear, large, round cell investing this, and called the germinal vesicle; a mass of granular protoplasm around this, called the vitellus or yolk.

(♂) This is a colorless body appearing just beneath the tentacles. It is made of small ectoderm cells of the ordinary type, of smaller cells without an endoplast and hyaline in aspect, and of cells like the last with a long filament attached to them. Within the cells, or free from them, are spermatozoa, the impregnating structures. They are oval buds, with one long cilium attached. By the coming of these motile spermatozoa in contact with the ovum of the ovary impregnation is effected.

(*l*) *Development.*—After impregnation the yolk divides into two. Then each of these divides again. Hence result four, and later eight and sixteen yolk segments. This process of binary sub-division continues until within the egg is a mass of many yolk segments. Each such segment is an embryo cell, and the whole is called the morula stage (*morus* = mulberry), because of the resemblance to a mulberry. The investing case of this mulberry mass is thickened and spiny. Now the egg is set free from the parent, and acquiring cilia upon its exterior, swims about freely while the inner yolk segments liquefy. At the same time the outer segments condense into two membranes, the outer or ectoderm, the inner or endoderm. So that our animal now is a closed sac with two layers surrounding a liquid yolk. This is the planula stage. Later on the animal fixes itself by one end that becomes the hydrarhiza. The cilia vanish, the unfixed end thins away and forms a mouth. This is the gastrula stage. The edges of this mouth grow up into tentacles, and from the cells of the ectoderm the fibres of Kleinenberg are formed. This is the actinula stage.

(*m*) *Classification.*—Kingdom Animalia. As the Hydra has not a body-cavity and a digestive cavity clearly marked off one from the other, it is of the sub-kingdom Cœlenterata. As its body and digestive cavities are actually one and the same, it is of the class Hydrozoa. As it is a simple animal, of the order Hydridæ. Genus, Hydra. Species, viridis (green) or fusca (brown).

PRACTICAL WORK.—(1) Draw without magnifying. (2) Draw under low power. (3) Search for mouth. (4) Stain with magenta, and observe the thread-cells. (5) Tease into small pieces, and observe cells of different layers and the fibres of Kleinenberg. (6) Make transverse and longitudinal sections of Hydra hardened in chromic acid.

CHAPTER X.

X. Sea-Anemone or Actinia.

(*a*) *Structure.* — (1) Occurrence. Sea-Anemones are marine animals very widely distributed over the earth. They are familiar to us upon the rocks between high and low water mark.

(2) Size. Their size is very various. Every gradation is met with between quite small animals, not more than a centimetre in diameter, and the gigantic ones that are as much as a decimetre in diameter.

(3) General structure. The Sea-Anemones are bag-like beings, fixed by a base, and with many tentacles protruding at the free end. But they are not simple, undivided bags, as are Hydræ. Each is rather a bag slung up within another. A vertical section through an Actinia reveals to us that the animal consists of an outer sac, the cavity of which is the somatic cavity, and of an inner smaller sac, conjoined with the other at the mouth end, but not conjoined with it below. The cavity of this inner, smaller sac is the gastric cavity. But the large investing somatic cavity is not simple. Vertical partitions run from the outer wall across it to the gastric wall, and thus divide the general cavity of the body into a number of rooms or loculi. These partitions are mainly of ectoderm, and are known as mesenteries (μεσος = middle, εντερον = intestine), and the rooms they separate are sometimes called mesenteric chambers. These loculi, or mesenteric chambers, have often openings in their outer walls that place their cavities in direct communication with the exterior. Two of the separating, mesenteries at opposite ends of a particular diameter of the Sea-Anemone, are often different in appearance from the rest. If the reader will picture to himself a large external bag with a smaller one suspended within it, and vertical folds running from the inner side of the former to the outer side of the latter,

he will see that the lower part of each vertical fold, or mesentery, will be free at its inner edge. For the gastric cavity does not reach so far down as the somatic cavity, and there is a space between the lower end of the former and the base of the latter. The free edge of the lower part of each mesentery is generally considerably thickened. The thickened part is the craspedum (*crassus* = thick, *pes* = foot).

The somatic cavity, of which mention has been so frequently made, is an instance of an enterocœle (κοιλος = hollow), *i.e.*, a body-cavity not wholly disconnected from the digestive one. But although here, as in Hydra, the two communicate, and therefore in each case the name "enterocœle" should be employed, in the Sea-Anemone we have an advance upon Hydra, for in the latter the two cavities that are here partially differentiated one from the other were reduced to one cavity.

The walls of the body are of ectoderm and endoderm, and there is a well-marked middle layer or mesoderm. But the constituents of these layers are cells, except in the case of the mesoderm, where distinct elongated fibres occur.

(*b*) *Digestion.*—(1) The food. Organic material floating, alive or dead, in the surrounding water.

(2) The organs. The food is usually caught by the many tentacles that encircle the mouth. The mouth is not a circular opening. It is elongated in one direction (the oral axis). In direct continuity with the ends of this long diameter are two folds that run down into the gastric cavity as vertical ridges upon its inner wall. The food passes through the mouth into this suspended cavity, and thence into the central part of the somatic chamber below. This central, undivided part may be regarded as a commencing intestinal canal. Some process of digestion takes place, and the digested food can pass easily from the central undivided space into any one of the loculi, all of which open into this space.

(*c*) *Absorption.*—The endodermal lining of the loculi must serve as a general absorbing membrane.

(*d*) *Circulation.*—As in Hydra, the body is filled more or less completely with a chylaqueous fluid, *i.e.*, a fluid that is largely watery, but that contains also corpuscles like the white blood corpuscles of higher animals. The movements of the animal, as it sways to and fro upon its fixed base, may cause a flux and reflux of this fluid that would be a very general sort of circulation.

(*e*) *Respiration.*—As in Hydra.

(*f*) —

(*g*) *Nervous System.*—In the base are some fine nerve cells and fine nerve fibres. The nerve cells are fusiform or spindle-shaped, and with the general appearance of cells of this tissue that is described in the account of the frog. These cells are joined by nerve fibres, and thus a rudimentary plexus is formed in the foot of the Sea-Anemone. A similar plexus is said to be present near the eyes that are described in the next paragraph but one.

(*h*) *Sense Organs.*—(1) Touch. The many hollow tentacles seem to be tactile. They are hollow inasmuch as they are the roofs of the intermesenteric rooms pushed upwards. That they are very sensitive organs all visitors to the sea-side will bear witness.

(2) Sight. Just outside the circle of tentacles in many Actiniæ are seen brightly-colored, bead-like bodies. These, at first named chromatophores (χρωμος = color, φερω = I carry), are now regarded as rudimentary eyes. Each of them is a little process of the body-wall with four layers visible. (*a*) The outermost one is of many bacilli or minute rods closely set together. (*β*) Next to the bacillar layer is a layer of rounded bodies that refract light strongly. (*γ*) Then follows a layer of cones that also refract light very powerfully. (*δ*) Most internally is a nervous layer of cells and fibres.

(3) Under this head I must mention the thread-cells or nematocysts. They are numerous in Actinia as in Hydra, and their structure is the same in the two animals.

(*i*) *Motor Organs.*—The mesoderm is principally made up of muscular fibres, and by their contraction the swaying movements of the animal upon its fixed base are performed.

(*k*) *Reproduction.*—(1) Agamogenesis. Gemmation is the only method of asexual reproduction certainly known. From any part of the body of the Sea-Anemone buds may be given off. They are formed in the same way as are those of Hydra, and the gemmation is discontinuous, *i.e.*, in the Sea-Anemone the buds are thrown off from the parent and live independent lives. In many of the allies of Actiniæ the gemmation is continuous and compound animals result. If in the walls of these colonies hard material is deposited as calcium carbonate, corals are formed.

(2) Gamogenesis. The Sea-Anemone is bisexual, and even in the same mesentery male and female organs may be found. For the reproductive organs are located in the mesenteries. It will be remembered that the lower part of each mesentery is free internally, because the gastric cavity is not so long as the somatic. Each mesentery is double, and at this lower free part the two folds are separated, and between the two layers of the mesentery are placed the sexual organs, spermatozoa or impregnating agents, ova or eggs to be impregnated. The method of impregnation is by diffusion of the spermatozoa into the water, and a kind of haphazard fertilisation must take place.

(*l*) *Development.*—The egg, as in Hydra, consists of a central dot, the germinal spot, a clear space around this, the germinal vesicle, a mass of vitellus or yolk, the whole invested by a distinct membrane, the vitelline, or yolk membrane. After impregnation, binary division of the yolk takes place until the yolk is segmented and the morula stage is reached. The central embryo cells liquefy, the peripheral ones form a double membrane of colored hypoblast (the future endoderm) and colorless epiblast (the future ectoderm). This is the planula stage. The colorless epiblast is ciliated. Next a mouth is formed, appearing first as an oval depression. Apparently this mouth and the gastric cavity into which it leads are formed by invagination, *i.e.*, by an infolding at one point of the body so that the lining of the gastric cavity is *ecto*derm, and is in continuity with the external lining of the body. The cilia form a curious little tuft at the fixed or aboral (*ab* = from, *os* = mouth) end of the body, and after a while disappear altogether. Next the hypoblast excavates, and, splitting into two layers, leaves an intermediate cavity, the body-cavity, or enterocœle, which, by the thinning away of the layers intervening between it and the gastric cavity, is brought into connexion with the latter. Then the oral opening alters its shape and elongates in one direction, the oral axis. The mesenteries develop next. Each is a double fold of the lining of the enterocœle, or body-cavity, probably mainly made up of mesoderm. The order of their development is so peculiar, and the way in which by them the body-cavity is divided into loculi is so remarkable, that I quote the full and clear description given by Professor Huxley upon pages 157, 158 of his "Anatomy of Invertebrate Animals" (1877): "The first which make their appearance are directed nearly at right angles to the oral axis near, but not exactly in, the centre of its length. Hence they divide the enterocœle into two primitive chambers, a smaller (A) at one end of the oral axis, and the larger (A′) at the other. This condition may be represented by $A \div A'$, the dots indicating the position of the primitive mesenteries, and the hyphen that of the oral axis. It is interesting to remark that, in this state, the embryo is a bilaterally symmetrical cylindrical body, with a central canal, the future gastric sac; and, communicating therewith, a bilobed enterocœle, which separates the central canal from the body-wall. In fact, in principle, it resembles the early condition of the embryo of a Ctenophore, a Brachiopod, or a Sagitta.

"Another pair of mesenteric processes now makes its appearance in the larger chamber A′, and cuts off two lateral chambers, B B, which lie between the secondary mesenteries and the primary ones. In this state the enterocœle or somatic cavity is four-chambered $\left(A \div \genfrac{}{}{0pt}{}{B}{B} A'\right)$. Next a third pair of mesenteries appear in the smaller chamber (A), and divide it into three portions, one at the end of the oral axis (A), and two lateral (C C). In this stage there are, therefore, six chambers $\left(A \genfrac{}{}{0pt}{}{C}{C} \div \genfrac{}{}{0pt}{}{B}{B} A'\right)$; but almost immediately the number is increased to eight, by the development of a fourth pair of mesenteries in the chambers B B, which thus give rise to the chambers D D, between the primitive mesenteries and themselves. The embryo remains in the eight-chambered condition $\left(A \genfrac{}{}{0pt}{}{C}{C} \div \genfrac{}{}{0pt}{}{D\,B}{D\,B} A'\right)$ for some time, until all the chambers and their dividing mesenteries become equal. Then a fifth and a sixth pair of mesenteries are formed in the chambers C C and D D; two pairs of new chambers, E and F, are produced, and thus the Actinia acquires twelve chambers $\left(A \genfrac{}{}{0pt}{}{C\,E}{C\,E} \div \genfrac{}{}{0pt}{}{F\,D\,B}{F\,D\,B} A'\right)$, five of which result from the sub-division of the smaller primary chamber. The various chambers now acquire equal dimensions, and the tentacles begin to bud out from each. The appearance of the tentacles, however, is not simultaneous. That which proceeds from the chamber A′ is earliest to appear, and for some time is largest, and, at first, eight of the tentacles are larger than the other four.

"The coiled marginal ends of the mesenteries appear at first upon the edges of the two primary mesenteries, then upon the edge of the fourth pair, and afterwards upon those of the other pairs."

(m) Classification.—Kingdom, Animalia. Sub-kingdom, Cœlenterata. As we have a double sac, one part of which, the outer or somatic part, includes the other, the inner or gastric, though the two open one into the other, the class is Actinozoa (Actinia-animals). As the allies of this animal produce coral, the order to which it belongs is the Coralligena (coral-producers). Genus, Actinia. Species, holsatica is a common one.

PRACTICAL WORK.—(1) Draw the animal whilst alive. (2) Try the effects of mechanical, thermal, chemical stimuli, with especial reference to the movements of the tentacles. (3) Kill and harden in chromic acid. (4) Make a longitudinal, vertical section through the middle and draw the parts. (5) Make a transverse section across the Actinia and draw. (6) Get out a mesentery and observe the thickened edge. (7) Tease out part of body-wall and make out cells of ectoderm, fibres of mesoderm, cells of endoderm. (8) Transverse section of tentacle. (9) Thread-cells. (10) Search between folds of lower free part of a mesentery for ova or spermatozoa.

CHAPTER XI.

XI. The Fern.

(a) Structure.—As we are coming now to large and familiar organisations, the method of study under the first division of our plan will vary somewhat from that hitherto adopted.

(1) Occurrence. Ferns are very widely distributed in the tropical and temperate regions. Any ordinary English fern will serve the student's purpose for study. The Bracken, the Hart's-tongue or the Maiden's-hair are preferable to any of the large tropical tree-ferns.

(2) General structure. A fern presents three chief organs: the rhizoids or rootlets, the rhizome or stem, and the fronds or leaves.

(*a*) The rhizoids. This term is used whenever a root-structure is not developed directly from a radicle or embryo-root. All the root-structures of Chara and of the Fern are of this kind. From the underside of the stem, and often from the lower part of the leaves, these structures are given off into the ground. They are thin dark threads. A transverse section of one examined under the microscope presents a distinction of tissues not yet encountered in our studies. On the outside is a marked layer known as the epidermis. The mass of the rhizoid enclosed within the epidermis is of cells, and is the fundamental or cellular tissue or parenchyma. Running through the centre of this fundamental tissue, and, therefore, seen in transverse section as a dot, is a single thread or bundle of harder, darker tissue. This is made up of fibres and vessels. In short, within this little rhizoid we meet for the first time with the three great tissues of vegetables. Until now we have had scarcely anything but cells to study. Here appear fibres and vessels. A fibre is an elongated cell with its wall thickened, *i.e.*, the cellulose wall is no longer the sole strength and stay of the cell. It has deposited upon its inner surface harder layers of tissue of material other than cellulose. That material is lignin (*lignum* = wood). And lignin is much more rich in carbon than is cellulose. The secondary deposits serve to give strength to the wall of the elongated cell. They are not generally, however, continuous. They are wanting at certain parts of the wall, and hence, though strength is acquired, fluids may yet pass from fibre to fibre by osmosis through the unthickened portions. A vessel is a longer tube, resulting from the obliteration of the partitions intervening between a number of cells placed one above another. Suppose many cells placed in a longitudinal series. Suppose the septa between each pair to disappear. A tube results, formed out of many cells, and such a tube is a vessel. If, however, the cells remain perfectly unmodified the tissues that are formed are cellular or fundamental, whilst the epidermal or outside tissue is of cells that are flattened and rectangular, but are not fibres, and have not conjoined to form vessels. Summing up the tissues not only of the Fern but of higher plants, we have the cells as basis, with cellulose wall, protoplasmic contents: a tissue formed of such cells, little or not at all changed, is fundamental. If the outer cells become flat and rectangular the tissue they form is the epidermis. If the cells elongate and have thickened walls they are fibres, and the tissues made of fibres are fibrous. If the cells fuse one with another, and a long tube is formed, that is a vessel, and the tissues formed of vessels are vascular. As the two last, fibres and vessels, are generally associated, the student will often hear and read of fibro-vascular tissues. The growth of the rhizoid is not throughout its length. It grows by cell division just within the apex. The actual apex is hard, protective, and is the root-cap.

(*β*) The rhizome or stem of most English Ferns is underground. It has been named rhizome from ῥιζα = root. A rhizome is a usually horizontal subterranean stem. In the Fern it is brown of hue, and traced from its oldest to its youngest part presents the remains of old leaves of former years attached to the parts known as nodes. Between the nodes are internodes, and presently the student finds a node that bears the leaves of the actual year of examination. At the extreme end, where the rhizome is at its youngest, the rounded, hair-covered apex is found.

To study the tissues of the rhizome, a transverse section, and then a vertical one, should be made. The following parts are to be seen from without inwards in the former section. (i.) The brown epidermis. (ii.) The brownish sub-epidermis, forming a zone within the epidermis. The cells here are rather long, rather thick, and without starch. (iii.) Fundamental tissue forming the mass of the stem. The cells here are polygonal and rich in starch. (iv.) Usually two very dark-brown patches, the transverse sections of two longitudinal and waved plates that run the length of the rhizome. These often lie about midway between the circumference and the centre of the stem. They are of true fibres. In the sub-epidermal zone we saw a gradation of the ordinary cell towards these. In these dark-brown patches we have true fibres, and tissue wholly made of these is called sclerenchyma (σκληρος=hard). The fibres are not thickened over the whole extent of the wall. The secondary deposit is wanting at certain places. Besides these two main bundles of fibres or of sclerenchyma, several small ones are often placed between these and the circumference. (v.) Two lighter colored yellowish-brown bundles within the two chief sclerenchymatous ones, and also a few of the same kind between the latter and the circumference again. These yellowish bundles are vascular. One of them carefully analysed in longitudinal section shows the following parts. Upon the exterior we have a number of sheath-cells without starch and forming an investing layer. Next to this sheath a single layer of ordinary cells smaller than the former and containing starch. Next in succession come several rows of bast or liber cells, small, rectangular, thick-walled, seven or eight times as long as they are broad. Then one or more rows of larger cells with very slightly thickened walls. Lastly, we have the vessels. These long tubes have been formed by the conjoining of several cells, each of which had been strengthened by secondary deposits. Hence the vessels have walls with secondary deposits on them. As these deposits are laid down in the form of simple transverse bars, the appearance presented is that of a vessel with a number of horizontal thickenings running across its wall. Such vessels are called scalariform (*scala*=a ladder). A few vessels in the vascular bundle of a fern have the thickening continuous as a spiral, and not broken up into many horizontal pieces. These are called spiral vessels. These vascular bundles can and often do join with each other.

(γ) The leaf, or frond. Rising from the rhizome are the fronds, or leaves; they present a leaf-stalk or petiole (*pes* = foot) or rachis (*rachis* = spine), and a lamina (plate), or blade. The surface of the petiole is covered by broad, brown scales, called ramenta or paleæ. These are only extensions of the epidermis. To any extension of the epidermis the name of trichome is given (θριξ, τριχος = hair). These ramenta are therefore trichomes. A transverse section of the petiole, which is brown when underground, green when above, reveals an epidermis upon the exterior, of elongated, rectangular cells, that are sometimes a little irregularly thickened; fundamental tissue making up the chief part of the petiole, its cells polygonal and containing chlorophyll; regular pale bands, that are the sections of vascular bundles, running up from the rhizome to the blade of the leaf. Each of these bundles has a sheath of fibres (prosenchyma), and contains spiral and scalariform vessels. Here, then, is an instance of a true fibro-vascular bundle. The lamina, or leaf-blade, is sometimes simple, as in Hart's tongue. More frequently it is divided into pinnæ, or leaflets, that are generally, in their turn, sub-divided into pinnules. The histology of the blade presents an epidermis, a cellular part, fibro-vascular bundles. But the epidermis of the lamina demands a special notice. Upon the upper side it is of flattened cells with a somewhat irregular outline. Upon the lower side the outline of the epidermal cells is sinuous or waved, and the contiguous cells seem to lock into each other. From this lower epidermis depend many trichomes in the shape of hairs, and the microscope reveals the fact that there are openings in this under-covering of the leaf. These openings lead into the spaces between the cells of the leaf, and put these intercellular spaces into communication with the outer air. Each opening is called a stoma (στωμα = mouth). Each stoma is bounded by two special cells that differ in shape from the other cells of the epidermis. They are kidney-shaped or reniform, and, by the incurving of their inner edges, leave a space between them that is a stoma. The two guard cells, or stomatal cells, differ from others of the epidermis, in that they contain chlorophyll. All other cells of the epidermis are entirely colorless. No chlorophyll is found in them. The fibro-vascular bundles make the veins and veinlets of the leaf. The fundamental tissue form all the part between the veins, and is called the mesophyll (μεσος = middle, φυλλον=leaf). It is not quite uniform throughout; for the cells of the lower half of the mesophyll are more stellate or irregular in shape than are those of the upper, and hence leave more space between them.

(*b*) *Digestion.*—The food of Ferns is that of plants generally. It is inorganic or mineral. From the air its general surface takes in gases: from the soil its rhizoids take in water and salts in solution. Carbon dioxide, water, ammonia are the chief food-stuffs, and these, it must again be noticed, contain the four chemical elements, carbon, hydrogen, oxygen, nitrogen, that go to make up plants.

(*c*) *Absorption.*—Not distinct from the last function.

(*d*) *Circulation.*—In plants we have a fluid, the cell-sap, that in some senses may be said to represent the blood of animals. This cell-sap is formed within the protoplasm of the cells. That protoplasm becomes vacuolated, *i.e.*, certain watery regions appear in the protoplasm, and as these increase in size and in number they run together and form a little mass of watery fluid. This water may hold in suspension or in solution all sorts and conditions of things, and the watery fluid with its contained substances is the cell-sap. That this is nutritive may be, I think, admitted. That there is a movement of this fluid is probable. That there is a movement of water in the plant is certain. But the student must not think of that movement as a determinate and constant one, like that of the blood of animals. There is no flow up and flow down in regular succession. Such movement as does take place is through the cells and fibres, not through the vessels of the Fern. Its causes are—

(1) Root-pressure. If fluid is constantly taken in by the roots, that fluid which is already in the plant is likely to be forced up towards the upper parts.

(2) Osmosis. As the upper parts of Ferns generally are constantly giving off moisture by evaporation, any given

cell or fibre in the plant is likely to have a fluid within it, rather more dense than the fluid in the cell or fibre immediately below it. Hence greater flow from the lower cell or fibre to the upper one, and a slow movement of the water upwards.

(3) Determination towards growing parts. Wherever water is wanted, as in the processes of growth, thither will the water move. And this is probably true of other constituents of the sap of plants. So that while it is not quite possible to speak of a definite flow of the whole mass of sap, its constituent parts may be said to undergo considerable movement. Those that are wanted at a particular part of the plant are slowly transferred thither. Those that are being formed at particular places are slowly transferred thence. The movements of the sap are rather intrinsic than *en masse.*

(*e*) *Respiration.*—The general facts of respiration, already often mentioned, obtain in the Fern as in other living things. Every living cell of the Fern, as it lives, gives out carbon dioxide and takes up oxygen. These gases going from or to the cell must pass through the cell-walls by the process known as diffusion, *i.e.*, they become dissolved in the water that saturates the walls of the cells, and through that are conveyed from place to place. Besides this movement of diffusion, there is a much more general movement of gases in the vessels. These long tubes appear to be great gas-carriers. The intercellular spaces also play their part in the distribution of gases. The actual elimination of oxygen and in-taking of the carbon dioxide, occurs at the surface of the plant as a whole. The general surface is still in a sense the respiratory organ. By it not only carbon dioxide, but a considerable quantity of steam is eliminated, part of which, at all events, is the product of oxidation of the tissues, the hydrogen of these tissues uniting with the oxygen taken in during respiration and forming steam. But it must not be forgotten that besides the mere getting rid of the gaseous products of decay (an essentially respiratory process), the Fern and all higher plants give off a great deal of water by the process of transpiration or by simple direct evaporation. It is impossible to think that all the water thus given off is the product of the decay of the tissues. The amount of this transpiration is largely determined by the size of the stomatal openings at the time. But the amount of respiratory steam evolved will have no relation to the condition of these openings. It is given off by the general surface as a whole.

(*f*) — (*g*) — (*h*) — (*i*) —

(*k*) *Reproduction.*—(1) Agamogenesis. Ferns at times are reproduced asexually by buds or gemmæ that are thrown off from their fronds.

(2) Gamogenesis. The process of sexual reproduction in this class of plants is complex. Upon the back of the fronds, either close to the margin of the leaf or else quite upon the back, and in relation generally to one of the veins, are found brown patches. Each patch is a sorus. It is often covered by a transparent fold of epidermis, the indusium. A sorus under a low magnifying power resolves itself into a number of little cases called sporangia, thecæ, spore-cases. Each of these spore-cases is a trichome. At first it is only a single cell, but by development of this is formed a biconvex multicellular organ generally upon a stalk. Along one edge of the biconvex case is in most Ferns a strong thickening of transverse bars called the annulus or ring. This, drying in the later summer time and contracting, causes a rupture of the thinner walled parts of the sporangium. Mixed with the sporangia are often found imperfectly developed threads, the paraphyses (παρα = by the side of, φυσις = nature).

The sporangium contains spores. A spore is a single cell with a double coat. The outer coat is the exospore, the inner the endospore. This spore, often thrown to some distance from the sporangium that contained it, and the Fern that bore it, under favorable circumstances germinates. A hypha is given out and almost at once upon its emergence from the spore gives off the primitive rootlet. The hypha itself divides by transverse septa, and presently the cells at the free end are divided by longitudinal ones also. Thus is formed a flat, cellular expansion, the prothallium, some of the cells of which again divide perpendicularly so as to increase its thickness. At one part the cells develop chlorophyll, and the prothallium gives off rhizoids from its under surface. The prothallium developes upon the surface of the soil: within it are formed the true sexual organs, so that thus far the reproduction has been agamogenetic, and now the gamogenetic commences.

♂ Antheridia appear at first as round or oval outgrowths of the prothallium, by division of its under cells close to the rhizoids. They are ultimately of a hemispherical shape. The outer layer of the cells constituting an antheridium, contains chlorophyll; the cells included in this chlorophyll-bearing outer layer are many and small. Within them appear the spermatozoids or antherozoids. These are spiral: one end is thin, and they are armed with many cilia. The thicker end has often attached to it a round mass containing chlorophyll granules.

♀ The Archegonia are found where the prothallium is more than one layer of cells in thickness, near the concave border. They are cylindrical. The outer cells are transparent without chlorophyll, and are ranged in four rows round a row of axial cells. These axial cells all disappear, save the lowest of them. This basal one is granular, large, nucleated. It is the embryo-cell. It has to be impregnated by the spermatozoids from the male organ ere a new Fern grows.

(*l*) *Development.*—It is evident that much of the development of the Fern has been studied in the investigation of the function of reproduction. It only remains to tell briefly of the changes of the embryo-cell. This cell divides into four cells. The two lower divide again, and form a kind of plug of cellular tissue that is imbedded in the substance of the prothallium. Possibly this cellular plug helps in transferring to or, it may be, in forming food for the young plant. This young plant is developed from the two upper cells of the four into which the embryo-cell is divided. Of these two, the upper one develops into the first rhizoid of the Fern, the other into the rhizome. Differentiation of the tissue of this rhizoid and of this rhizome takes place. From the rhizome the fronds are developed. These are at first curled up like a shepherd's crook, and this arrangement is called circinate (*circino* = I twist).

(*m*) *Classification.*—Kingdom, Vegetabilia. Sub-kingdom, Cryptogamia. Group, Cormophyta. As the order of development is spore, prothallium, reproductive organs, plant, spore again, the Fern belongs to the division Pteridophyta (πτερις = Fern). As there are sori upon the leaves, and the fertile leaves are not confined to a particular region of the stem, the class is Filicineæ. As the spores are all alike, and the plant is isosporous (ισος = the same), the order is Filices. The genera and species vary too much for me to give any special names.

Practical Work.—(1) Rhizoids. (α) Draw as a whole. (β) Transverse section. (γ) Longitudinal section. (2) Rhizome. (α) Draw as a whole. (β) Transverse section. (γ) Longitudinal. (δ) Boil a piece in nitric acid, and examine for vessels. (3) Fronds. (α) Draw as a whole. (β) Ramenta. (γ) Transverse section of petiole. (δ) Upper epidermis. (ε) Lower epidermis. (ζ) Vertical section of leaf. (4) Reproductive organs. (α) Sorus. (β) Single sporangium. (γ) The same ruptured. (δ) One spore. (ε) The same germinating. (ζ) A prothallium. (η) Vertical section through a prothallium. (θ) Antheridia. (ι) Antherozoids. (κ) Archegonium.

CHAPTER XII.

XII.—FLOWERING PLANT.

(*a*) *Structure.*—(1) Any flowering plant will serve the purpose of the student fairly well. Of course, the particular one chosen will vary with the season and the locality. One thing very important to remember is that the study of one flowering plant alone will be of but little use. The best plan is to dissect many plants, so as to familiarise oneself with the parts common to all, and at the same time with the variety of ways in which they are arranged and are developed. The only certain way by which the student can make himself acquainted with the general structure of flowering plants is by observing, dissecting, and describing a great many different kinds. The written description of them is of great importance. In the writer's "Botanical Tables for the Use of Students," a plan upon which to describe flowering plants and certain tables necessary for that purpose are given. Any student who will read carefully that which is to be written in the succeeding pages could easily, by aid of the tables, describe flowering plants. If it were possible to obtain an ideal series of plants for the student to investigate, perhaps the following list might serve: Buttercup, Sedum, Primrose, Bean, Violet, Oak, Lily, Orchid. My description will, therefore, be a general one of flowering plants, though I shall, upon occasion, make reference to one or other of the above-named familiar plants.

(2) General structure. A flowering plant, like Chara and the Fern, presents a central axis and certain lateral appendages. The axis has one part immersed in the soil, the other raised into the air. The former descending portion of the axis is the root. The latter ascending portion is the stem. The appendages are stem-like offshoots, the branches, and special organs upon the stem or upon its branches, known as leaves. The morphology and the histology of each of these organs

will be considered. Morphology (μορφη = form) is the study of the structure of organs. Histology (ʽιστος = web) is the study of the structure of tissues.

(*a*) Root. (i.) Morphology. The root, or descending axis, presents sometimes one main central piece in the same line as the primary stem. This part is the primary root; and a plant whose root shows this primary part plainly is said to have an axial or tap-root. The roots of the Buttercup, Sedum, Primrose, Rose, Violet, Oak, are all of this kind. All roots given off laterally from this primary root, or from other parts of the plant, are secondary. Some plants, as the Lily and the Orchid and the Grass, have not a central main root-axis. Nothing but secondary roots or rootlets is known. Such roots are said to be adventitious (accidental), or secondary roots. To the various shapes of roots special names are given, for which the reader is referred to botanical glossaries, or, better, to a good practical teacher. Roots do not carry leaves.

(ii.) Histology. Before entering on the histology of the root, the student is reminded that the cell is the unit of vegetable structures; that an elongated thick-walled cell is a fibre; that a vessel results from the fusion together of super-imposed cells; that a collection of not greatly changed cells is fundamental tissue, or parenchyma; that a collection of fibres is fibrous tissue, or prosenchyma; that a collection of vessels is vascular tissue; that these two last are usually associated, and form fibro-vascular bundles; that the flattened external layer of cells is the epidermis. The roots of flowering plants have a root-cap. This is a cap covering the extremity of the root. It is difficult to see in plants whose roots are plunged in the soil, because the ends break off so readily. But the roots of Lemna, the duckweed, hanging down into the water of stagnant ponds, when placed under a one-inch objective, show the root-cap very well. It is wholly cellular and of several layers of cells, is fixed to the apex of the root, and runs up the side of the root for some little distance as an investment. A transverse section of the root reveals the following parts from without inwards. An outer covering, or epiblema, fundamental tissue, a single cylindrical mass of fibro-vascular bundles, surrounding a pith or medulla of fundamental tissue. Taking each of these in succession, the epiblema is epidermis minus stomata. The general structure is that of epidermis, already described. But no openings are present, and usually the trichomes, or root-hairs, are well developed. The fundamental tissue making the greater part of the mass of the root, and that in the pith are normal. The fibro-vascular bundle needs special attention. The most external layer of this bundle is cellular, and is capable of growth and development. This is called the pericambium (περι = around, *cambio* = I nourish). From it the secondary roots take origin, and with it the soft part of the root just within its actual apex is connected. The lines of origin of the secondary roots correspond exactly with the wood-bundles in this fibro-vascular bundle. For within the circumferential pericambium of the bundle occur vertical rows of wood-tissue and vertical rows of bark-tissue that run the length of the root. Usually there are two, three, or four of the wood-bundles and as many of the bark-bundles. More than these are occasionally seen, as in some of the Lily order. This is the first time we have encountered wood and bark as histological constituents. It is, therefore, necessary to give a clear account of them once for all. That which is now to be said is true of wood and of bark generally, and in an examination should be clearly stated whenever these structures are mentioned, whether in connexion with roots, or, as is far more likely to occur, in connexion with the stem.

Wood or xylem (ξυλον = wood) is broadly distinguished by its cells being strengthened by lignin and filled with air. Xylem is therefore firm and brittle. Bark or phloem (φλοιον = bark) is broadly distinguished by its cells being softer and more flexible, and containing sap. Passing to a more detailed account, xylem shows three chief elements. These are true vessels, already described, true fibres, already described, cells, forming the xylem parenchyma. The phloem shows three elements. Sieve-tubes, with unthickened side-walls, but with thick transverse walls, where the original cells joined end on. The thick transverse walls are perforated. Fibres (bast-fibres) like those of wood, but more flexible and containing sap. Cells that form the bast or phloem parenchyma. These cells are longer than those of the xylem, and are filled with fluid. Often they are called cambiform. The fibres of the phloem constitute the hard bast: its sieve-tubes and cells the soft bast. Just within the root-cap is the cellular, growing layer, a full account of which will be given under the head of development.

(β) The stem. (i.) Morphology. There are three chief kinds of stem. If, as in the Buttercup, the stem is green, soft, delicate, it is herbaceous. If, as in the Oak, it is darker in color, hard and strong, it is woody, and we have a tree. Intermediate to these ranks the shrub. Of this the Rose is an example. Various terms are used in describing stems. These have reference to their direction, shape, surface. But for these, the student is advised to consult descriptive works or a good teacher. Upon the stem buds are seen. They are usually in the axils of the leaves borne by the stem, and are called axillary. If they are not in the axils of leaves, they are called adventitious. From these buds branches or flowers are developed.

(ii.) Histology. A transverse section of an ordinary English herbaceous stem, such as that of a Bean-plant, reveals the following parts in succession from without inwards. Epidermis. This calls for no special comment. Sub-epidermal parenchyma or parenchyma of the bark, the mesophloeum or middle bark. This is a succession of many layers of round, chlorophyll-bearing cells. Fibro-vascular bundles. A number of these are generally present. Each of them is wedge-shaped, with the narrow end of the wedge turned inwards towards the centre of the stem. Taking one fibro-vascular bundle, its parts from without inwards are as follows. Phloem or bast or liber (endophloeum); a layer of fusiform cells, round in transverse section and with thick walls. Cambium, of cells that are small, angular, thin-walled, with granular contents. These cambium-cells are in direct continuity with the apex of the stem. Xylem; small fibres with thick walls and vessels intermingled with the fibres. The vessels are often spiral, and this structure is especially seen in the vessels situate in the part of the bundle nearer the centre of the stem. But, besides the spiral vessels, others are seen in which the secondary deposit is not in a spiral, nor is it in the form of transverse bars, as in the scalariform vessels of ferns. The deposit in these vessels that are so characteristic of the wood of flowering plants is laid down much more continuously than in either of the cases just mentioned. It is not, however, quite continuous. Imagine a layer of lignin deposited all over the inner surface of the cellulose wall except at certain small places. It is laid down as a kind of perforated membrane. As successive layers are deposited, each concentric with the first and with the original cellulose wall, they encroach more and more upon the cavity of the cell, and make the wall thicker and thicker. But the perforations in them all correspond. Thus many canals are formed that run through the thickness of these strengthening layers, and are only closed by the thin cellulose wall upon the exterior. This arrangement admits of the easy passing of fluid from vessel to vessel, despite the great strengthening of the walls.

In the very centre of the stem of most English plants is the pith or medulla, of cells once more, and connecting this with the cellular layer of the bark are plates of cellular tissue that in the transverse section appear as radiating lines. These are the medullary rays.

(γ) Leaves.—(i.) Morphology. Three leaf regions are known, each of which presents different kinds of leaves. The bulb of a Lily or Hyacinth shows the first region. The white scales forming the larger part of the bulb are leaves, and this region is called the leaf-scale region. The ordinary leaves of an ordinary plant, green, air-surrounded, are the second kind. The flowers are of modified or metamorphosed leaves, and constitute the third region. Their parts are the floral leaves.

The morphology of the leaf-scales or cataphyllary leaves (κατα = down, φυλλον = a leaf) is very simple. They are nearly flat, colorless scales.

The morphology of the ordinary leaf. A leaf-stalk in many cases, not in all; a blade almost always; and at the base of the leaf-stalk a leaf-sheath that is far more frequently wanting than present. The stalk is the petiole. If it is wanting, the leaf is sessile (*sedeo* = I sit). The blade is the lamina. Its veining, its shape, its margin, apex, surface, all require in descriptive Botany special terms. The sheath or vagina is seen in the leaf of the Rose or of the Bean. It is a leafy expansion (double in both these plants), visible at the region where the petiole joins the stem. When it is thus double, the two parts are called stipules.

The morphology of the floral leaves. If an ordinary flower is carefully picked to pieces four circles of organs are seen. Thus a Buttercup presents from without inwards a circle of green leaves, a circle of yellow leaves, a number of yellow threads, a number of green bodies. The outermost circle of green leaves is collectively the calyx. Its individual members are sepals. The second circle of yellow leaves is collectively the corolla. Its individual members are petals. The mass of yellow threads is collectively the andrœcium (᾿ανηρ = man, ᾿οικος = house), for each of its individual threads or stamens is a male organ. The green bodies in the centre of the flower are collectively the gynœcium (γυνη = woman), for each of its individual bodies or carpels is a female organ. If another flower — *e.g.*, the Sedum — is examined, the sepals making up the calyx, the petals making up the corolla, the stamens (only ten in Sedum) making up the andrœcium, and the carpels (only five in number) making up the gynœcium, will be found. In the Primrose the chief changes are that the sepals are joined one to the other; the petals are joined one to the other, and the carpels are all welded together into a single, flask-shaped structure, the gynœcium. Further, in the Primrose the five stamens of the andrœcium are joined to the corolla. In the Bean plant the calyx has its sepals conjoined; the corolla has five very irregularly shaped petals; the stamens are ten, and nine of them are conjoined, and the gynœcium has only a single carpel. In the Violet the sepals and petals are very irregular in shape, the five stamens are also odd of form, and the flask-shaped gynœcium has three carpels joined together in its structure. The Oak is curious, because the male and female organs are in different flowers, and the corolla is altogether wanting. In the Lily the two outer circles, calyx and corolla, are alike, and, as it is not easy to distinguish the one from the other, they are named collectively the perianth (περι = around, ᾿ανθος = flower). So also in the Orchid we have a perianth of two circles or whorls, and the name perianth is used generally when it is impossible to see a clear distinction between the sepals and the petals. In the Orchid the andrœcium is represented by one stamen only, and the remarkable gynœcium is of three united carpels.

Let us now consider each of these whorls in detail. Calyx. Of green leaves called sepals. These last vary in *number*, although five is a very common number. They may be joined together. Then the calyx is gamosepalous (γαμος = union). Or the sepals may be distinct. If the sepals are joined at their bases, the lower conjoined part is the tube; the upper part, where the sepals are free, is the limb.

The corolla is of leaves called petals that are usually colored. The petals are often, but not always, five in number. They may be joined (corolla gamopetalous) or distinct. If the petals are joined, the words tube and limb are used in the same sense as that in which they are employed in regard to the calyx.

The morphology of the Androecium and of the Gynœcium will be better considered under the head of Reproduction.

(ii.) Histology. Of the leaf scale. A mass of cellular tissue; each cell without chlorophyll and generally rather more flattened than spherical in shape.

Of the ordinary leaf. The petiole. A transverse section of the petiole of an ordinary flowering plant presents an epidermis upon the outside, fundamental tissue making up, as usual, the mass of the organ, and amidst this the cut ends of vertical fibro-vascular bundles, derived from the xylem and the phloem of the stem. The lamina. The exterior of this part of the leaf is of epidermis. In our temperate climate the epidermis is of one layer of cells. The cells are flattened and rectangular in shape. Openings, the stomata, are found between them that lead into the intercellular spaces of the leaf. The structure of these stomata and of their guard-cells is the same as that of the fern stomata and fern guard-cells. The stomata are far more numerous upon the under surface of the leaf than upon the upper. The mesophyll, or cellular tissue of the leaf, lies between the upper and the lower epidermis, and is traversed by the veins or fibro-vascular bundles. Its cells are of a cellulose wall, primordial utricle, protoplasm with vacuole and endoplast, and generally starch. The cells of the mesophyll nearest to the upper epidermis are oblong in shape, with the longer diameter vertical and contain chlorophyll. Those of the epidermis are without chlorophyll. The cells within the lower epidermis are stellate or star-shaped. These also contain chlorophyll. So that the mesophyll is green, and as the cells of the upper region are more closely packed than are those of the lower, we can understand the deeper green of the upper side of the leaf as compared with the lower. The veins, or fibro-vascular bundles, are of xylem upon the upper side that is in continuity with the xylem of the stem, and of phloem upon the under side that is in continuity with the phloem of the stem. The sheath, or vagina, has the same histological composition as the lamina.

Of the floral leaves. Each individual member of each whorl of the flower is a metamorphosed leaf. The sepals and petals are leaves very little transformed. They have epidermis, which upon the outer side, that corresponds with the under side of the leaf, is provided with stomata. They have fundamental tissue, the color-matter in which is chlorophyll in most sepals, and in most petals is that modification of chlorophyll that gives a yellow, or a blue or a red hue. Traversing this fundamental tissue, as the veins or fibro-vascular bundles traverse the mesophyll of the leaf, are spiral vessels. The fibro-vascular bundles are here reduced to their most delicate constituent.

The histology of the Andrœcium and of the Gynœcium will be studied under the head of Reproduction.

(*b*) *Digestion.*—The food of flowering plants is inorganic. Carbon dioxide, water, ammonia, are the three chief food-stuffs. Salts also are of importance. A good fluid in which to grow flowering plants is water that has in solution potassium nitrate, KNO^3; calcium nitrate, $Ca\,2\,NO^3$; potassium sulphate, K^2SO^4; iron sulphate, $FeSO^4$; magnesium sulphate, $MgSO^4$.

The organs that take in the food are the roots and the green parts. From the soil the roots absorb water with salts in solution. Many of these salts are nitrates, and many are ammonium salts. Ammonium has for symbol, H^4N. Hence the roots may be regarded as the organs that take in the nitrogenous parts of the food, for experiments, notably those of Lawes, Gilbert, and Pugh, have shown that nitrogen, as nitrogen, is not taken in from the air as a food-stuff by plants. On the other hand, the green parts take in food from the air, and the chief material thus ingested is carbon dioxide. Of this the carbon is fixed and the oxygen given out. Hence the roots take in the nitrogen-containing food-stuffs, and the leaves especially take in the carbon-containing food-stuffs. From the roots the former must move up until they meet the latter coming down from the green parts. Where the two sets of food-stuffs meet, the manufacture of those important plant-structures that contain carbon, hydrogen, oxygen, nitrogen, must occur, and from the place where this manufacture occurs, diffusion of these substances to other parts of the plant must follow. So that, as has been well said, the flowering plant is as to its roots a fungus, needing no light and making nitrogenous things out of inorganic materials; and as to its green parts an alga, fixing carbon with the aid of sunlight. There are no openings for the intaking of food in either roots, or leaves, or stems. All is done by the general surface. This taking in of food is often called Assimilation (*ad*=to, *similis*=like). And to the various processes whereby the first materials thus formed are changed into the many things that are manufactured out of them, the general name of Metastasis, or change, is given. Contrasting the two processes, we find that—

Assimilation takes place in parts containing chlorophyll.
Metastasis takes place in all parts.
Assimilation needs light.
Metastasis does not.
Assimilation liberates oxygen.
Metastasis uses up oxygen.
Assimilation increases the plant's weight.
Metastasis diminishes the plant's weight. For in the transformation changes work is being done and waste must ensue.

(*c*) —

(*d*) *Circulation.*—(*e*) *Respiration.*—All that was said under these heads in the history of the Fern applies here.

(*f*) *Secretion.*—For the first time we can speak clearly under this heading. Secretion (from *secerno*, *secrevi*, *secretum*=I separate) is the separation of special things from the blood or from the sap, to be either used again or eliminated as injurious to the body. An organ that thus secretes is called a gland. In the human body, *e.g.*, the liver is a gland, secreting from the blood bile that is partly of use in the body again, partly excrementitious. Flowering plants present certain organs that must be called secretory. The trichomes are often glandular hairs, as in the sting of the nettle. In the epidermis of many plants are little masses of cells that secrete a viscid matter. In some parts of the flowers are cellular organs that form nectar or honey. These last glands are called nectaries. They can be seen at the base of a buttercup petal upon the inner side. Upon a few plants, as the Sundew, very remarkable glands are met with, that secrete a true digestive fluid capable of digesting animal matters. (See the author's "Student's Darwin," p. 111.) In the intercellular spaces of some plants much secretion is formed. The resin of the pine-trees is an example.

(*g*) *Nervous system.*—(*h*) *Motor Organs.*—(*i*) *Sense Organs.*—Under these heads in an elementary book nothing can be said. But the young student is warned that certain remarkable responses to stimuli, transmissions of influence from one part to another, and movements are observable in plants, and make us believe that ere long we may have to discuss at far greater length the question of a nervous and of a muscular system in plants.

(k) Reproduction.—Agamogenesis is effected through the agency of buds or slips. These removed from the parent plant will under favorable circumstances grow up into a new being, like that whence the gemma was taken.

Gamogenesis. The account of this must commence with a description of the morphology and histology of the sexual organs.

(1) Morphology. Andrœcium, of stamens. Each stamen has generally a lower thread-like part, the filament (*filum* = thread), and a cap at the summit of this. The cap is an anther. It is of two lobes placed side by side. The line between them is the furrow. Each lobe is hollow, and contains a yellow dust, the pollen. This is the fertilising agent of the male organ. A fine vertical line is generally visible running down the front face of each anther-lobe. This is the line along which the anther-lobe will open, and thus be able to discharge its contained pollen.

The gynœcium is of carpels, but these carpels are generally joined together. Let us consider, first, a Buttercup or a Sedum. Here the carpels are quite free one from the other. In the Buttercup they are many: in the Sedum, five. If a single carpel of either of these plants is examined, it is seen to have a swollen base. This is the seed-case or ovary. In the Buttercup this little case ends in a minute point, the stigma. In the Sedum a like terminal point exists, but it is separated from the ovary by a thread-like stalk, the style. So that a carpel consists, as a rule, of ovary, style, stigma. Within the ovary, if it is opened, is found in Buttercup one unripe seed or ovule. Within each of the five ovaries of Sedum are several ovules. The one ovule of Buttercup and the several of Sedum are attached to a ridge upon the interior wall that is known as the placenta. In most plants the carpels are conjoined. Thus, in the Primrose, the globular ovary, the single style, the rounded stigma, are probably each five-fold. The five carpels are joined together into one gynœcium. Even when the ovary of Primrose is opened, no trace of the complexity of this gynœcium is evident. It has only one room or cell within it, and all the ovules are placed upon a placenta that rises as a column free from the side-walls, and taking origin from the centre of the base or floor of the ovary. The Bean-plant has a gynœcium of one carpel only, and in it the long ovary, the curved style, the minute stigma are all well marked. The Violet has three carpels united together. If its ovary is cut across transversely, though only one cell is seen within, the ovules are found ranged upon the walls in three sets. The Lily also has three carpels in the gynœcium, and here a section of the ovary shows three cells or rooms, each completely shut off from its fellow.

The placenta calls for special notice. It is the part of the ovary to which the ovules are attached. In the separate ovaries of the Buttercup and of Sedum and in the one ovary of the Bean-plant, this placenta is formed from one carpel only. Now, a carpel, like every other part of the flower, is a metamorphosed leaf. The metamorphosed leaf in becoming a carpel has been so folded upon itself that the two edges have joined together and enclosed the cavity of the ovary. The two joined edges, or margins of the leaf, have made a ridge upon the interior of the ovary, and to this ridge the ovules are attached. This ridge is the placenta, and as it is made up of the margins of the carpel leaf it is called marginal.

In the Violet and Orchid, when the ovary is cut across transversely, three sets of ovules are found. They are placed on the walls of the ovary, for the gynœcium is in these plants formed of three carpels placed side by side, and the margins of each of the three united with the adjacent margins of the two contiguous carpels. No one of the three leaves has folded in so completely as happens in the case of the Buttercup. Each has been folded in a little, and then one of its edges joined to the edge of the carpel-leaf to its right and the other to the edge of the carpel-leaf to its left. Thus we have a one-celled ovary with three ridges on its walls, each ridge made up of the margins of two carpels. This kind of placenta is called parietal (*paries* = wall).

In Lily and in many other plants, as, *e.g.*, Fuchsia, Foxglove, Geranium, more than one carpel is concerned in making up the gynœcium. But in all these plants the individual carpels have been completely folded upon themselves, so that each has its own margins united and each encloses its own individual cavity. Thus results an ovary with as many cells as there are carpels, and with all the placentæ meeting in the middle or axis of the ovary. Each placenta is here formed of the two margins of one carpel-leaf. The arrangement is, in short, a multiple of the marginal arrangement seen in the single carpel. As all the placentæ, one for each cell, meet in the axis of the ovary, these placentæ are called axile.

(2) Histology. Andrœcium. The stamen is a metamorphosed leaf. Its filament is the petiole: its anther, the lamina. The filament has epidermis externally, fundamental tissue making up the mass of the thread, and a single bundle of spiral vessels as sole representative of the fibro-vascular bundles. The filament ends above in the connective, a part that joins together the two anther-lobes. Each anther-lobe has two walls, the outer or exothecium (ϵξον = without, θηκα = covering), the inner or endothecium (ϵνδον = within). The outer is epidermal in its nature, and its cells are smooth-walled. If the anther is not to open, and some anthers remain closed, the endothecium cells are also smooth-walled. But in all anthers that dehisce or open to discharge their pollen, the cells of the endothecium are fibrous, *i.e.*, they have secondary deposits. In the majority of anthers that dehisce longitudinally down the suture all the cells of the endothecium are fibrous. When the parts of the flower exposed to the summer sunlight begin to dry the cells of the exothecium, contracting more strongly than the strengthened fibrous cells of the endothecium, cause a tension in the anther-walls that ends in the walls rupturing

along the weakest line, and that weakest line, where both coats are thinnest, is the vertical line known as the suture.

The histology of the pollen-grain. Each pollen-grain is, as a rule, a single cell with ultimately two walls. The outer wall is epidermal, often covered with spines, ridges, warts. It is the extine. The extine is generally perforated at certain points and coated with a viscid oil. The inner wall is of pure cellulose, thickened at certain points that correspond with the perforations in the extine. This inner coat is the intine. Within these two coats is the fovilla (*foveo* = I nourish). This is of protoplasm, dense, coarse-grained, with starch and oil intermixed.

The carpel is a metamorphosed leaf. Hence the outer wall of the ovary is epidermal, and often provided with stomata. The thickness of the wall is of fundamental tissue traversed by spiral vessels as the sole remaining representative of the fibro-vascular bundles, whilst the inner lining of the ovary is that modification of epidermis usually known as epithelium, destitute of stomata and of trichomes. The structure of the style and stigma is on the same plan. The placenta is for the most part cellular, but spiral vessels pass into it and from it to the ovules it supports.

The ovule is as a bud on the margin of the carpel-leaf. It is often connected with the placenta by a stalk, the podosperm (πους, ποδος = foot, σπερμα = seed) or funiculus (*funis* = cord). Essentially the ovule consists of a central mass of cells, the nucellus, invested by two coats also cellular. The inner of these is the primine (*primus* = first), the outer is the secundine. The point of junction of the podosperm with the rest of the ovule is the hilum. The point of junction of the secundine with the nucellus is the chalaza (χαλαζω = I feed). These two points do not always correspond, as might at first be imagined, on account of the twisting of the ovule that occurs in many cases. As the two coats do not completely surround the nucellus, an opening is left between them called the micropyle (μικρος = little, πυλος = gate). The three kinds of ovule depend upon the relative positions of the parts just named. If the nucellus is straight with the hilum below and the micropyle above, the ovule is orthotropous or atropous (ορθος = straight or α = without, τρεπω = I turn). This is seen in the Dock. If the ovule is tilted up so that the hilum is uppermost, the micropyle lowermost, the nucellus inverted, and the podosperm adherent to the side of the ovule, so as to form a raphe (ridge), the ovule is anatropous (*ανα* = up), as in Buttercup. If the nucellus and its coats are curved, horse-shoe fashion, the hilum and the micropyle, both being close to the placenta, the ovule is campylotropous (*καμπυλον* = horse-shoe). An example of this kind of ovule is seen in the Pink or the Chickweed. The two latter of the three forms are more common, and have probably been naturally selected, as it is of great advantage to a plant to have the micropyle near the placenta as it is in these two cases.

Now that the morphology and histology of the organs concerned are understood, we can study the process of reproduction. The one essential is to bring pollen and nucellus together. For within the pollen-grain is the fovilla, or impregnating matter, and within the nucellus is developed, near its upper part, a special cell, the embryo-sac and within this embryo-sac, the protoplasm, aggregating together into one or more masses, has formed one or more oospheres. Unless one of these oospheres is impregnated by the fovilla of the pollen-grain, gamogenesis will not take place. The rest of the embryo-sac, *i.e.*, the part of it not occupied by oospheres, is filled up with a mass of cells known as endosperm, or badly, as the albumen of the seed.

The first question is as to the manner of transference of the pollen-grain. The difficulty is really greater than at first sight it seems to be. For we tend to think that the pollen of a given flower always fertilises the ovule of the same flower. But the researches of Darwin, in England, and of Gärtner and Kölreuter in Germany, have shown that this self-fertilisation is very rare. Cross-fertilisation is the rule; that is, the fertilisation of the ovule of a given flower by the pollen from another flower of the same kind. The whole of this most important question with its immense consequences is discussed more fully than it can be here in the writer's "Biological Discoveries and Problems" under Reproduction. The transference of the pollen that must take place if cross-fertilisation is to be effected is brought about either by the wind or by insects. Flowers like the Oak that are aided by the wind, whose pollen is borne by the wind, are called anemophilous (*'ανεμος* = wind, *φιλεω* = I love). Plants whose pollen is carried from flower to flower by insects are called entomophilous (ϵντομον = insect). These latter, such as the Violet, and, indeed, all the plants named at the beginning of this chapter, except the Oak, are attractive to insects by their color, shape, odor, and nectary. When by the wind or by an insect the pollen of a flower is carried to the stigma of another flower of the same species, if that stigma is ripe, a quantity of fluid is found upon it. This fluid the pollen-grain absorbs. The grain now begins to grow. The hard extine does not alter, but through its apertures the soft, continuous intine protrudes in the form of a hypha, called the pollen-tube. This tube goes down the canal of the hollow style, fed on its way by the rich, protoplasmic conducting tissue that partly blocks the canal. At last it reaches the ovary. There it follows the line of the placenta, which is also covered with conducting tissue. Close to the placenta are the micropyles of the ovules. The pollen-tube turns up into one of these, forces its way through the nucellus, and its contents, the fovilla, pass into the embryo-sac and fertilise the oosphere.

Looking back for a moment, homologies and analogies between the Fern and flowering plants may now be considered.

FERN.	FLOWERING PLANT.
Sporangium.	Anther or ovule.
Male spores, producing only prothallia that carry antheridia.	Pollen-grains.
Hypha given out by one spore.	Pollen-tube.
Female spore, producing only prothallia that carry archegonia.	Embryo-sac.
Prothallus. ♀	Endosperm.
Embryo-cell of archegonium	Embryo-cell, or oosphere after impregnation.

(*l*) *Development.*—The plastid oosphere, impregnated, takes to itself a wall, and is an embryo-cell. This divides into two, one of which, undergoing yet further division, becomes a thread or suspensor that supports the product of the division of the second cell. This second cell undergoes considerable binary division, and after a while the little rounded mass of cells thus formed begins to separate into three regions. Of these, the one that points to the micropyle is the rudimentary root or radicle. Another region, at the opposite end of the embryo to the radicle, is the rudimentary stem or plumule. Enveloping these is one rudimentary leaf, or there are two rudimentary leaves, the cotyledons. These three parts are easily made out by scraping off the outer coats of a bean, and splitting it into two halves. These white halves are the cotyledons, and nestling between them at their edges are the pointed radicle and the flattened dentate plumule. At first all these three parts are wholly cellular. The cotyledons contain much starch and other nutrient matter. This they give up to the young root and stem. These parts grow by cell-division. The radicle, piercing the seed coats, plunges into the soil as the root. The plumule grows upwards into the air as the first bud of the stem. From the stem, later, leaves and branches are given off, and yet later those modified branches that we call flowers. To trace out the full history of the development of every part of a flowering plant would carry us far beyond the limits prescribed for this book. But a word or two upon the development of the root, of the stem, of the leaf, and of the pollen, may with advantage be said.

The growing part of a root is just within the root-cap, and is of many thin-walled cells in close contact, and very rich in protoplasm. This tissue is the primary meristem. This primary meristem may show as many as four distinct layers (Hydrocharis), but in most roots certain of the typical layers are blended. From without inwards the layers that may be present are the calyptrogen (καλυπτρα = covering), whence the root-cap is developed; the dermatogen (δερμα = skin), whence the epiblema is developed; the periblem, whence the cortical part, if present, is developed; and the central plerome, whence originate the axial tissue and the fibro-vascular bundles. In most plants with adventitious roots the second and third of these, dermatogen and periblem, are fused together, and in most plants with an axial root the first and second, calyptrogen and dermatogen, are conjoined.

In the study of the development of the stem we find that its growing point is of primary meristem, and that this presents the three inner layers of the four seen in the root.

There is no calyptrogen, as the stem has nothing corresponding with the root-cap. But the dermatogen is there, and from it the epidermis is formed. Within it is the periblem of several layers, and from this the cortical tissues arise; while the centre of the growing point is a cylinder of plerome, whence the xylem, phloem and medulla are formed.

In the development of the leaf we must remember that the growth is centripetal (*centrum* = centre, *peto* = I seek). Leaves grow from their bases, not at their apex.

Pollen-grains. Each of the cells within the double wall of the anther-lobe is a mother-cell of a pollen-grain. Each of these mother-cells divides into four special mother-cells. Each of these last forms within itself by free-cell formation a pollen-grain. By the solution of the walls of the special mother-cells, and of the mother-cells, the pollen-grains are set loose in the cavity of the anther.

(*m*) *Classification.*—All flowering plants belong to the kingdom Vegetabilia. As they have stamens and carpels, they are of the sub-kingdom Phænogamia (φαινεω = I appear). This sub-kingdom is divided into two classes, the marks of which, and of their chief subdivisions, will be better understood if I here transcribe the table upon page 9 of my "Botanical Tables for the use of Students."

Flowerless plants: without stamens and carpels. CRYPTOGAMIA.				*Seaweeds.* *Fungi.* *Mosses.* *Ferns.*
Flowering plants: with stamens and carpels. PHÆNOGAMIA.	Root adventitious. Wood irregular. Leaves parallel-veined. Parts of the flower in 3. Seed with one cotyledon. MONOCOTYLEDONES.		Perianth none or rudimentary: glumes GLUMACEÆ.	*Grass.*
			Perianth none: spadix SPADICIFLORÆ.	*Arum.*
			Perianth petaloid PETALOIDEÆ.	*Lily.*
	Root axial. Wood in rings. Leaves reticulate. Parts of the flower in 2 or 5. Seed with 2 cotyledons. DICOTYLEDONES.	Seeds not enclosed in ovaries GYMNOSPERMÆ.		*Conifers.* *Cycads.*
		Seeds enclosed in ovaries ANGIOSPERMÆ.	Petals wanting INCOMPLETÆ.	*Stinging-nettle.*
			Petals united and hypogynous COROLLIFLORÆ.	*Dead-nettle.*
			Petals on calyx CALYCIFLORÆ.	*Rose.*
			Petals distinct and hypogynous THALAMIFLORÆ.	Buttercup

Practical Work. — (1) Description of many plants. (2) Vertical section of root. Study root-cap in Lemna. (3) Transverse section of root. (4) Of herbaceous stem. (5) Vertical of herbaceous stem. (6) Boil fibro-vascular bundles in weak nitric acid, and study under high power. (7) Sections of young buds. (8) Transverse section of petiole. (9) Vertical of lamina. (10) Epidermis from under side of leaf. (11) Transverse section of young flower-bud. (12) Histology of sepal. (13) Of petal, with special reference to spiral vessels. (14) Transverse section of filament. (15) Vertical of filament. (16) Draw anther, not magnified. (17) Histology of anther-lobe. (18) Pollen. (19) Draw gynœcium, not magnified. (20) Epidermis of ovary. (21) Epithelium of ovary. (22) Transverse section of ovary. (23) Of style. (24) Sections of stigma and style of Evening Primrose for pollen-tubes. (25) Ovules of Veronica serpyllifolia for entrance of pollen-tubes into micropyle. (26) Seeds of Canterbury Bell for embryo-sac and contents.

CHAPTER XIII.

XIII. Fresh-Water Mussel.

(*a*) *Structure.*—(1) Occurrence. Fresh-water Mussels are found in ponds and rivers. There are two kinds, but the general description now to be given applies to both, save in so far as regards the shell. The shell of Unio (the "union" of the last scene in "Hamlet") differs slightly from that of Anodonta, the animal whose shell will be described at length.

(2) General structure. The animal has a skeleton. A skeleton (σκελης = hard) is a hard structure that serves for the protection of organs and for the support of muscles. In the Mussel the skeleton is external. It invests the animal upon the exterior. It is, therefore, an exoskeleton. The two shells make up the exoskeleton. Usually they are called valves, and the pair of them constitute a bivalve shell. The two valves are joined together upon the dorsal, or back region, by a set of strong, elastic fibres. These fibres constitute the ligament, and by their elasticity keep the two valves apart, as far as their lower or ventral edges are concerned. So that in the normal, undisturbed condition of the Mussel, the two parts of the shell are slightly separated below, though they are conjoined above. When the two valves are completely approximated, certain muscles, called adductors, are contracting. If the animal is dead, the valves are permanently separated below.

Each valve is broader at one end than at the other. The broader end is that in relation to the mouth. The anterior end is broader than the posterior. Upon the dorsal border of each valve, near the tapering anterior end, is a blunt point, called the umbo. The external markings of the shell are a number of concentric lines, that are really lines of growth. The internal markings of the shell, visible when the animal has been removed from its covering, are two large, roundish ones, a smaller one near the posterior of the two large ones, and three lines, the one running along the shell parallel to its lower edge, the other two running from the umbo to the two larger marks. The two largest, roundish impressions seen upon the inner face of each valve are the points of attachment of the two muscles that bring the valves together. The smaller mark, near to the posterior of these, is the point of attachment of one of the muscles that retract the foot. The line running parallel to the lower edge of the valve is that of the attachment of certain muscles that connect the integument of the Mussel with its shell, and the lines from the umbo to the large muscle-marks are those showing the successive points of attachment of the shell-muscles as the animal grew larger.

Chemically, the shell is for the most part of calcium carbonate, $Ca\,CO^3$. Traces of calcium phosphate, $Ca_3\,2\,PO^4$, may be present, and small quantities of one or two other salts. A small percentage of animal matter is present. It is interesting to compare, for a moment, the chemical composition of the exoskeleton of this animal with that of the endoskeleton of higher animals. There is far more animal matter in bone than in shell. One-third of bone is animal matter, or gelatin. Again, in bone the larger part of the mineral constituents is calcium phosphate: in shell, it is calcium carbonate. The edges of the valves are generally soft, uncalcified, as their growth is continuous.

Within the two valves lies the body of the animal. The valves are placed to the right and left. They are lateral, and the body is bilaterally symmetrical, *i.e.*, a median vertical plane would divide the body into two exactly similar halves. The integument of the body, which, while it covers the other parts, secretes and is covered by the shell, is very smooth and well supplied with blood. It is known as the mantle or pallium, and presents two lobes, that correspond with the two valves of the shell. These two lateral mantle-lobes are free at their lower edges, which are considerably thickened. Upon the dorsal, or back region, they are united together at the front and behind. They join one the other before the mouth and they join one the other above and in front of the posterior termination of the alimentary canal. Between these two places of union the two mantle-lobes are connected with the dorsal edge of the outer gill. If, then, we trace one of the lobes from before backwards, we find it at first conjoined with its fellow, then bound on to the side of the body by its conjunction with the upper part of the outer gill, and then again joining its fellow at the posterior region of the body, and upon the dorsal side of the body. The ventral edges of the two mantle-lobes are practically free throughout their length and thickened. These three regions of the mantle, as far as the relations of its upper part are concerned, mark the animal approximately off into three parts. The part where the two mantle-lobes join one another in front of the mouth, and where the anterior of the two muscles that approximate the two valves of the shell is located, is the prosoma (προ = before, σωμα = body). The part where the two mantle-lobes are affixed to the side of the body, the part in which the gills and the foot hang down is the mesosoma, or middle body, and the posterior region of the Mussel, in which the two lobes again run into each other, and in which, also, lies the hinder of the two valve-approximating muscles, is the metasoma (μετα = after).

(*b*) *Digestion.*—The food of the Mussel is organic. For the most part it consists of the lower water-plants and of Infusoria. The food-supplies are brought to it by currents of water that are constantly setting in through the opening between the two valves below and between the thickened lower edges of the mantle-lobes. The cause and the course of this water-current will be considered under Respiration. In the present connexion it is enough to say that with it food-material is brought, and by it the food-material is carried up to the mouth, and excrementitious products washed away from the anal region. The mouth is in the middle vertical line of the body, and lies at the anterior broad end of the animal, near the dorsal surface. It is below and before the anterior of the two large shell-muscles, and is immediately above the foot. It opens into an œsophagus or gullet that passes under the muscle, and is short and wide. This œsophagus leads into a squarish stomach, and from the stomach the intestine follows a tortuous course in the foot of the Mussel. After leaving the stomach it passes downwards, then turns up again until it nearly reaches the dorsal or upper edge of the foot, again runs down into that organ, again turns up to the region of the heart, and then runs straight back as the rectum, along a horizontal, dorsal, median line *through* the heart to its ending. That ending, the anus, is also upon the middle line of the body, near the dorsal surface and near the posterior end of the animal. The opening is bounded above by the mantle-lobes, where they conjoin in the last part of their dorsal edges. So that the anus lies in the metasomatic region. Further, the opening is bounded below by a horizontal partition that joins together the two inner gills, *i.e.*, from the inner of the two gills of the one side of the animal to the inner of the two gills of the other side of the animal a horizontal partition runs across, connecting their upper parts. And this partition makes the floor of a chamber, the roof of which is formed by the posterior portions of the mantle-lobes. In this chamber the alimentary canal terminates. The chamber is therefore named the cloacal chamber (*cloaca* = a sewer). In other members of the class to which the Mussel belongs the margins of this chamber are extended to some distance, and the tube thus formed is the anal syphon.

(*c*) *Absorption.* —The digested food is absorbed by the blood-vessels that are present in large numbers in the walls of the alimentary canal. This is a considerable step in the direction of complexity. For in all the animals studied hitherto, whenever any absorption did take place, it was of a very simple order. Large surfaces—such as the lining of the body-cavity of the Sea-Anemone—performed the function. But here in the Mussel, the digested food is taken up by definite vessels in the walls of the intestine. The vessels are not wholly set apart for the function of absorption; for they carry blood also. Yet they are vessels performing more or less completely the function of taking up the digested food.

(*d*) *Circulation.*—(1) The blood. Colorless, without red corpuscles. But the white are present in large quantity, and are of the same nature as those of man, exhibiting considerable amœboid movements.

(2) The organs. Here for the first time we meet with a heart, *i.e.*, a pulsatile central organ driving the blood through a more or less complete system of vessels. The heart lies in the posterior half of the body, and upon the dorsal aspect in the middle line. Actually in the middle line is one of

its cavities. The other two lie, one on each side, to the right and left. The median cavity is the ventricle. The two side cavities are the two auricles. The auricles open into the ventricle, and the lips of the two openings are so arranged as to allow the passage of blood from the auricles to the ventricle, but not to allow a flow in the opposite direction. This heart, with its oval ventricle and its two pyramidal auricles is wholly surrounded by an enclosing vessel called the pericardium (*καρδια*=heart). The student of human physiology must be careful not to regard this pericardium as resembling the pericardium of the human heart in anything more than name and, roughly, position. Its function and structure are by no means the same as the function and structure of the pericardium of our heart. For this latter is a membrane that envelops the heart, and no blood passes through it on the way to that organ. But the pericardium of the Mussel is a vessel within which the heart lies, and through which the blood returning from the body passes on its way to the central organ.

From the ventricle two vessels are given off. One runs forwards above the alimentary canal: the other backwards beneath the alimentary canal. They are the two aortæ, anterior and posterior. Each gives off branches to the various organs of the body. These branches are arteries, for an artery is a vessel carrying blood centrifugally, *i.e.*, from the heart to the organs of the body. These primary arteries divide into many others, and at last the blood is no longer contained within arteries, or indeed within distinct vessels of any kind. It is found to be passing through lacunar spaces. In all the animals without backbones, in all Invertebrata, the system of vessels through which the blood passes is thus incomplete. The finely divided blood-vessels of the Vertebrata are in the lower animals represented by spaces or channels in the body organs that are not limited by any definite membrane. If I may use the phrase, the blood soaks through the tissues and organs. Ultimately, after passing through the lacunar spaces of the body, the blood gathers itself together from all parts into one large vessel that lies in the middle line of the body, below the pericardium and heart, and between the two important dark organs that are regarded as renal (*ren* = kidney), and are known as the organs of Bojanus. This median vessel, receptacle of all the used-up blood of the body, is the venous sinus or vena cava. Thence the blood flows, right and left, through the organs of Bojanus to the respiratory organs. From these it returns to the pericardium, and then through certain openings enters the two auricles and so to the ventricle, the aortæ, and the body generally. In the floor of the pericardium are small apertures that put the cavity of that organ into communication with the vena cava. To sum up, the course of the circulation in the Mussel is as follows. Ventricle, aortæ, arteries, their divisions, lacunar spaces, vena cava, organ of Bojanus, gills, vessels to pericardium, pericardium, auricle, ventricle again.

(*e*) *Respiration.*—By gills or branchiæ. A gill is an external organ that helps in the breathing of air dissolved in water. The gills of the Mussel are four in number, two on each side of the body, an inner and an outer. They hang down between and parallel to the two lobes of the mantle, whilst between the right and left inner gill depends the median foot. To the space enclosed between the two mantle-lobes, the space within which the gills and the foot hang, the name of branchial or gill chamber is often given. In some of the allies of the Mussel the margins of this chamber are extended forwards as a kind of tube, the ventral syphon. The water used in respiration comes into this chamber from below. The inhalent current, therefore, sets in from below; the exhalent sets out on the dorsal region from the cloacal chamber. We shall see directly how the water passes from the ventral side of the animal to the dorsal. Each of the four gills is plate-like or lamellar (*lamella* = a plate), and is double. It consists, in fact, of two plate-like dependent pieces that are joined at the lower border. The outer plate is of many vertical bars that run parallel to each other, and are made up of many transverse rods. The inner plate is made up largely of vessels, and has many clefts in it. These clefts lead into the cavity of the gill, which is bounded laterally by the inner and by the outer plate. As the margins of each cleft are fringed with cilia working inwards, a steady current of water sets in through the clefts of the inner face of each of the four gills into the cavity of each of the four gills. This cavity is crossed at certain levels by imperfect partitions that run from the inner side of the outer plate of the gill to the outer side of the inner. The four cavities of the gills open above into the cloacal chamber, the floor of which, where it is complete, is formed by the horizontal partition that joins the two inner gills with each other. The inner gills are joined anteriorly with the foot. But they extend further back than the foot. The part of each of them posterior to that organ is joined with its fellow by this horizontal partition. Hence the course of the water used in respiration is as follows. Entering between the separated shell-margins below, it passes between the thickened ventral edges of the mantle-lobes, up between the outer and inner gill of each side, and also between the inner gill of each side and the foot. Swept by the cilia that line the margins of the openings in the inner plate of each gill, it enters the gill-room. Traversing the whole vertical length of this room, the water emerges into the cloacal room above. Thence it passes out of the shell-cavity on the middle line dorsally.

(*f*) *Secretion.*—The separation of materials from the blood, to be used again in the body, or to be eliminated from the body, occurs in both forms in the Mussel. The organ that secretes a substance to be utilised is the liver. The organ that secretes substances to be eliminated is the organ of Bojanus.

The liver is in connexion with the stomach. It consists of many tubes, or follicles, that open directly into the stomach. Each tube is branched, and lined with a layer of brown epithelial cells. These cells are the probable secretors of the bile. They may be named the hepatic cells (*hepar* = liver), and are functionally in all probability akin to those of the Frog, described in the next chapter but one. The hepatic tubes, or follicles, are closed at the end remote from the stomach. The fluid secreted is probably of use in digestion.

The organs of Bojanus are two. They lie one upon each side of the vena cava, and immediately under the pericardium. Each presents above a thin, transparent membrane, below which lies a dark, pulpy-looking part, presenting a quantity of soft tissue, much excavated by lacunar spaces, through which the blood flows. The upper membranous part is called the non-glandular, and the lower, darker part, the glandular portion of the organ of Bojanus.

Of the two, the glandular portion extends rather further back than the non-glandular. The connexions of this organ with other parts are very important. It communicates with the pericardium and with the exterior. With the pericardium it is connected through two small oval openings at the extreme anterior end of the pericardium, just under the point where the intestine enters the pericardium upon its way to perforate the ventricle. By these openings the pericardium is put into communication with two channels that run along the glandular part of each organ. But this channel on each side turns upwards after running some little distance, and ends in an opening upon the upper side of the glandular portion that puts the latter into communication with the non-glandular part above. This latter opening is opposite the posterior end of the pericardium. Again, in the floor of the non-glandular part, at the front end, each organ of Bojanus has an aperture that leads into a channel running from the organ to the exterior. The external opening of this channel is close to and just above the attachment of the inner gill of the particular side to the mesosoma.

There are, then, three sets of openings. From the pericardium into the glandular part of the organ of Bojanus. This opening is at the anterior end of the pericardium. From the glandular to the non-glandular. This opening is opposite the posterior end of the pericardium. From the non-glandular to the exterior. This opening is hard by and above the place where the body and the inner gill conjoin anteriorly.

(*g*) *Nervous system.*—Well-developed. Three pairs of ganglia, or nerve-swellings, exist. One pair are to be found on the dorsal side of the mouth, just at the base of the possibly tactile organs, called labial palpi. This pair are the cephalic (κεφαλη = head). The Mussel has no distinct head or part of the body specially devoted to the carrying of the sense organs. But as this pair of ganglia represent those met with in the heads of other animals, they are named cephalic. These supply nerve-cords to the anterior part of the mantle, the anterior of the two muscles that approximate the shell-valves, the gills, the labial palpi, and the mouth. A second pair, the pedal, are in the foot, and the two are so closely approximated in the middle line of the body that they seem as one. This pair supply the muscles of the foot and ear. The third pair of ganglia are found upon the under face of the posterior adductor muscle, and are known as the parieto-splanchnic (*paries* = wall, *splanchna* = internal organs). They supply generally the mantle and the viscera or internal organs. They give nerves to the gills, to the middle and posterior parts of the mantle, to the posterior adductor, the heart and the rectum.

The cords connecting these ganglia are all in relation to the cephalic pair. They are:—a cord or commissure joining the two cephalic, and passing in front of the mouth: two cords or commissures joining the cephalic with the pedal or foot ganglia: two cords connecting the cephalic with the parieto-splanchnic. These last run through the organ of Bojanus and under the pericardium.

(*h*) *Sense organs.*—Close to the mouth, one on each side, are two triangular flaps, called the labial palpi. Possibly these are tactile.

In the foot are the auditory sacs. Each of these auditory vesicles is a sac containing fluid, and an otolith (*ους*, *οτος* = ear, λιθος = stone). This ear-stone is ever trembling. The walls of the sac are lined with epithelium that seems to be ciliated, and some of the cells appear to bear, instead of cilia, rod-like processes that remind us of the fibres of Corti in higher ears. Homologically, this ear of the Mussel would seem to be the vestibule of the ear of the Vertebrata.

(*i*) *Motor organs.*—The chief muscles are those to which reference has been made so many times: the two that bring the valves of the shell nearer together. They are the adductors (*ad* = to, *duco* = I draw). These run transversely across from one part of the shell to the other, perforating the animal. They are called respectively the anterior and posterior adductors. Besides these, two pairs of muscles serve to draw up the foot into the shell cavity after it has been protruded. These are the retractors (*retraho* = I draw back) of the foot. One pair of them, the anterior retractors, have origin from the valve of the shell upon each side immediately behind the point of attachment of the anterior adductor. The other pair, the posterior retractors, take origin from the valve of the shell upon each side immediately in front of the posterier adductor. The four retractors are all inserted into the upper part of the foot Again, intrinsic muscles of the foot are known, *i.e.*, muscles wholly within that organ. Lastly, the muscles of the mantle join the mantle-lobe of each side with the valve of the same side. Their successive areas of attachment to the shell-valve form the pallial line.

As to the histology of the muscles, we find a curious blending of the two structures that are respectively characteristic of the two kinds of muscles known as voluntary, or under the control of the will, and involuntary, or not under the control of the will. The muscles are made up of fibres that are of the same shape as the involuntary muscular fibres of man, *i.e.*, are fusiform. But each fibre under a high power, is granular within, and presents particles arranged in transverse rows that suggest the transverse stripes or striæ of voluntary muscle.

(*k*) *Reproduction.*—(1) Asexual or agamogenetic reproduction is no longer seen. Indeed, that method for reproducing the whole being is encountered only in the lower animals, though it is general in plants. A remnant of it is often preserved in the higher animals in their power of reproducing certain parts of themselves; but there is, I believe, no evidence as to the possession of even this power by the Mussel.

(2) Gamogenesis. The Mussel is unisexual, *i.e.*, each individual is either male or female. Of whichever sex the Mussel may be, the organs, whether testes or ovaries, are two, are lodged in the foot, and are largest in the winter. The external opening is near that of the organ of Bojanus. From this opening a duct can be traced inwards, giving off many blind branches, that, subdividing, make the sexual gland a racemose gland (*racemus* = a bunch of currants).

The spermatozoa of the male are short, rod-like, each with one long cilium. These organs cast into the water around either meet therein the ova, or are carried to the genital opening of the female by currents. The ova or eggs of the female are round. They have germinal spot, germinal vesicle, vitellus or yolk, and a vitelline membrane or yolk membrane. This last, whilst it surrounds the yolk, is extended at one place into a short tube that ends in an opening, the micropyle.

(*l*) *Development.*—After impregnation, the vitellus divides into many cells. But the cells are not all of the same size. Half the divisions of the yolk are larger than the other half, *i.e.*, one set of blastomeres are macromeres, and one set are micromeres. These two kinds of blastomeres multiply by division in the case of the large ones, by gemmation in the case of the small. As the central blastomeres return to the liquid state we have a hollow sphere, the blastosphere. The Mussel is now of one layer of cells, half of the sphere being of macromeres, the other hemisphere of micromeres. Amongst the macromeres are two much larger than the rest. They may be called megistomeres (μεγιστος = largest). Presently the half of the sphere that is made up of the small cells is invaginated within the other half that is made up of large cells. So that the micromeres constitute an inner layer or hypoblast, and the macromeres an outer layer or epiblast. The two megistomeres become enclosed between the hypo- and epiblast, and form the mesoblast.

From the epiblast, later on the ectoderm, are formed the following structures. The mantle. This appears as a dorsal patch with raised edges that extends downwards over the surface of the body, and is divided by a median furrow into two lobes. The shell. This is cuticular in its origin, and is not at first divided into valves. The velum. A disc with ciliated edges that appears at the anterior end of the body. Upon it is a central tuft of cilia that are much longer than those on the edge. Two involutions of the ectoderm are also seen. One is anterior, the mouth; the other is posterior, the byssus gland. The byssus is the threads that are best seen in the sea-water Mussel attaching the shell of the animal to rocks. These threads are secreted by a gland. Although the adult fresh-water Mussel has no byssus, the larval condition has this structure. The cephalic ganglia certainly, and the other nerve-ganglia probably, originate from the epiblast. The first-named are developed from two ciliated processes that appear in front of the mouth. The foot is an outgrowth of the Mussel-body along its inferior face, behind the mouth. Possibly mesoblast enters into its composition together with the epiblast. This may also be true of the gills in their development. The first part of the gills upon each side that is developed is the outer plate of the inner gill. This is formed by the blending of a number of filaments or threads that grow downwards from the anterior part of the mantle cavity, which is later on the gill-chamber, just at the point where the mantle and the mesosoma run into each other. These filaments multiply from before backwards, and join to form the outer lamina of this inner gill. The lower edge of this turns up on the side nearer the middle line of the animal, and this upgrowth, extending higher and higher, becomes perforated, and forms the inner plate of the inner gill. This last is now complete. From the upper part of the filament-formed plate (the outer of the inner gill) other filaments grow downwards upon the outer side, or upon the side that lies nearer to the shell-valve, and uniting form the inner plate of the outer gill of this side. Finally, the outer lamina of this outer gill is formed from the inner one by an upgrowth similar to that which, originating from the outer plate of the inner gill, formed the inner plate of this last.

The eggs are hatched in the gill-chambers, especially that of the outer gill of each side, and the beings thus formed are very different in aspect from the adult Mussel. So different are they that for a long time they had another name given to them, as they were thought to be parasites upon the Mussel. They were called Glochidia. Each of them has a bivalve shell, but the valves are triangular in shape. The two triangles are joined by their bases, and at the point of junction is an elastic hinge that keeps the valves apart below. The two apices of the valves are incurved, with a serrate or saw-toothed point. The mantle is very thin and delicate. It has upon each lobe three papillæ ending in fine filaments. The mouth is wide, and its margin ciliated. The foot is well-developed, and two filaments are formed representing the byssus of the Sea-mussel. After a time the Glochidia leave the gill-cavity of the parent, and usually affixing themselves to the tails of fish, undergo a metamorphosis that transforms them into the ordinary Mussel.

In the growth of the shell during the advancing life of the Mussel, the increase in thickness is due to the deposition of the fresh layers within the old ones, and the increase in area is due to the extension of the new ones beyond the limits of the old. The top of the umbo represents the original shell of the embryo.

(*m*) *Classification.*—Kingdom, Animalia. As the Mussel has a soft, external covering, the mantle, has gills, a shell, a foot, the sub-kingdom is Mollusca (*mollis* = soft). As the shell is bivalve, and the valves are placed laterally, as it has neither head nor teeth and its gills are plate-like, it is of the class Lamellibranchiata. As there are two adductor muscles present, the order is Dimyaria (δις = two, μυων = muscle). Genus, Anodonta. Species, Cygnœa.

PRACTICAL WORK.—(1) Draw the animal before it is killed, showing especially the external appearance of the shell-valve. (2) Draw the inner aspect of the shell, with especial reference to the muscular attachments. (3) After removal of one of the valves draw the side view of the muscle. (4) Turning up one of the mantle-lobes, draw the side-view as then shown. (5) Trace out the alimentary canal. (6) Dissect out pericardium, heart with its three cavities, the two aortæ, the vena cava. (7) Examine gills with the unaided eye: then small pieces of each lamina under the low, and then under the high power. (8) Examine blood under microscope. (9) Seek for hepatic follicles. (10) Dissect out the organ of Bojanus, noticing the glandular or secretory, and the non-glandular or duct-regions with the apertures. (11) Find cephalic, pedal, parieto-splanchnic ganglia. Also the three commissures. (12) Dissect out labial palpi. The ear is better found in certain other Lamellibranchiata, *e.g.* Cyclas. (13) Make out the adductors of the valves and the retractors of the foot. (14) Search in the foot for the sexual organs and products. (15) Study Glochidia. (16) Mark upon the exterior of the animal, after the valve has been removed, all the openings.

CHAPTER XIV.

XIV. CRAY-FISH AND LOBSTER.

THE Cray-fish will be taken as the type, and the differences between it and the Lobster will be pointed out.

(*a*) *Structure.*—(1) Occurrence. The Cray-fish most easy of access to the student are found in English rivers: the Lobster along the rocky coasts of European seas.

(2) General structure. An exoskeleton is present, though it is of an aspect very different from that of the Mussel. The most noticeable part of this outside hard covering, that serves for protection and the insertion of muscles, is that which is often called the shell, *i.e.*, the large shield-like covering that extends from the front of the body over the back and sides. This is the carapace. This carapace covers several of the many rings or divisions of which the body consists. These rings, segments, or somites, succeeding one another in linear order, fall into three sets: the head set, constituting the front of the body, the thorax set coming next, and the tail or abdomen set making the end of the animal. Of these three sets the first two (head and thorax) are covered by the carapace; the third, or abdominal set, run from the termination of the carapace to the posterior end of the body. That two sets of somites, cephalic and thoracic, are covered by the carapace is evidenced by a curved line that runs across it, and separates a smaller head region from a larger thoracic. This line is the cervical suture (*cervix* = neck, *sutura* = seam). It may be traced into continuity with a groove on each side of the animal's body. This groove, separating head and thorax laterally, is the cervical groove. The somites of the head are six in number. This will be better understood when we study the appendages of the head. But the six somites of which the head is composed do not all lie in the same plane. The *mouth* marks the region at which a difference of position

takes place. Thus, the segments in front of the mouth are all so arranged as to look forwards. But the segments behind the mouth all look downwards. And this bend of the ventral aspect of the body is the cephalic flexure. The head carries the mouth and sense-organs. The carapace has at its anterior end, in the middle line upon the dorsal region, a strong, serrated point, the frontal spine or rostrum.

The thoracic somites, covered by the hinder part of the carapace, are eight in number. They carry the motor organs. They need to form a firm support for those limbs, and are so conjoined as to make practically one strong box to which the limbs are affixed. In the Cray-fish the eighth thoracic segment is not ankylosed to the rest. In the Lobster they are all ankylosed together.

The abdominal somites are not conjoined. They are six in number and are freely movable one on the other, as they are connected by membrane. Each has a hard exoskeleton, but the rings formed by this exoskeleton are joined together by membrane. To the sixth somite is attached an organ sometimes regarded as a seventh. It is better considered as an extension of the last, or sixth, abdominal segment. This is a flat plate with a transverse groove, dividing it into two parts in the Cray-fish. No such groove is to be seen in the Lobster. This appendage, carrying no side-limbs, is called the telson. It is a prolongation of the dorsal surface of the sixth abdominal somite in the middle line.

The parts of a typical somite are well seen in the third or fourth abdominal. After studying either of these, it should be compared with each of the other nineteen. A typical somite is arched dorsally, flat ventrally. The arched dorsal part is the tergum (back). The anterior part of the tergum is smooth, and runs over the rough posterior part of the tergum of the somite in front. The sides of the somite are formed by the two pleura (ribs). These run downwards from the tergum, and join the external part of the ventral aspect of each somite on each side. This external part of the ventral aspect of the somite is limited externally by the pleuron, internally by the point of attachment of the appendage of the side under consideration. This point, when the appendage has been removed, is a hole. The epimera (επι=upon, μερον=part), or external portions of the ventral region of the somite, lie between the pleura and the regions of attachment of the limbs. Finally, the part of the ventral region of the somite that lies between the two appendages is the sternum (breast-bone). Tracing the somite round from the top, we have then the tergum, pleuron, epimeron, attachment of an appendage, sternum, attachment of the other appendage, the other epimeron and pleuron, the tergum again.

(*b*) *Digestion.*—The food is organic and animal. The Cray-fish will feed upon living or dead animal matter, even if either of these takes the form of a brother Cray-fish. The wide mouth is on the under side of the head, just behind the cephalic flexure. It is bounded above by the labrum, or upper lip, shield-shaped, soft, but with calcareous plates in each lateral half: below, by the metastoma (μετα = after, στωμα = mouth). This also is soft, and divided into two lateral lobes, each with two calcareous plates, while between them is an oval process with bristles at its end. Labrum and metastoma are extensions of the sterna of the two somites that bound the mouth in front and behind. The side boundaries of the oval aperture are six pairs of appendages. The mandibles (*mando* = I eat) are strong, and toothed on the inner edge. This inner edge is double. The two parts are separated by a deep excavation. To the anterior edge is attached an extension, the mandibular palpus. The outer edge is concave, and the posterior has inserted in it the tendon of the muscle which approximates the mandibles. If we think of the four margins of the mandibles, the front, inner side, back, outer side in succession, we shall find that the front has attached to it the palpus, the inner has the excavation and the double row of teeth, the posterior has the muscle-insertion, the outer is concave. The second and third lateral boundaries are the maxillæ, lateral jaws like the mandibles, but not toothed and not nearly so powerful. The maxillæ are leafy or foliaceous, and to the second pair are attached the organs that play an important part in respiration. The fourth, fifth, sixth of the pairs of mouth appendages are the feet-jaws, or maxillipedes, that combine the nature of the feet with that of jaws. They are really the homologues of the three pairs of legs of Insecta. Each has a basal joint next the body with three processes projecting from it. The basal joint is the protopodite : the internal one of the three processes, *i.e.*, the one nearest the middle line of the body, is the endopodite; the middle, the exopodite: the external, the epipodite. Structurally, they are intermediate between the jaws just described and the walking legs. These, then, are the boundaries of the mouth: the labrum above, the metastoma below, the mandibles, two pairs of maxillæ, three pairs of feet-jaws at the sides.

The wide mouth leads into a wide œsophagus, running up and back, and with plaited walls. This opens into a large stomach, extending forwards and backwards. It presents two divisions; an anterior larger, the cardiac, a posterior smaller, the pyloric. The anterior half of the cardiac division is membranous and ciliated internally. On the walls of the posterior half, and of the pyloric part, is the calcareous gastric skeleton. This presents a T-shaped piece, whose cross-bar, the cardiac plate, runs transversely across the cardiac part of the stomach, whilst the longitudinal bar, urocardiac (ὀυρα =tail), runs in the middle dorsal line as far back as the anterior part of the pyloric region, into whose cavity it projects. To the under side of the posterior end of this urocardiac ossicle are attached two cardiac teeth. Reverting to the transverse cardiac ossicle, from whose middle point the urocardiac runs backwards, we find two ossicles attached to its ends right and left. These running downward and slightly backwards, not in the middle line, are the antero-lateral or ptero-cardiac ossicles. With the lower hinder end of each is connected a large, long ossicle, the postero-lateral or zygo-cardiac, that runs up and back, and joins in the roof of the anterior portion of the pyloric region a transverse bar, the pyloric ossicle. This is jointed on with the longitudinal urocardiac by a prepyloric ossicle, that runs from the pyloric in the roof of the hinder part of the stomach down and back to the end of the urocardiac, in the cavity of that hinder part. The inner edges of the postero-lateral ossicle, thickened and ridged, are the lateral cardiac teeth, and the prepyloric carries on its under end a urocardiac tooth. Hence results in the stomach a hexagon, whose anterior side is the cardiac ossicle, the posterior the pyloric; the two lateral on each side are the ptero-cardiac in front, the zygo-cardiac behind. The hexagon is bisected longitudinally by the urocardiac. This, running further back than the pyloric, is connected with the latter by the prepyloric running forwards and upwards. The edges of the zygo-cardiac upon each side are teeth. The urocardiac carries at the under side of its posterior end two teeth. The prepyloric carries one inferiorly, and the sides and lower surface of the cardiac have let into them several plates carrying the infero-lateral cardiac teeth.

The chief muscles concerned in moving this very complex apparatus, and bringing its teeth together "with a clash," are four: an anterior pair, from the carapace in front to the cardiac roof; a posterior pair, from the carapace behind to the pyloric and zygo-cardiac ossicles.

During spring and summer two calcareous plates, "the eyes," are in the side walls of the cardiac part. Arising from the inferior wall of the stomach, where the two parts join, is a large process that runs upwards, and is bilobed. The pyloric portion is ridged internally: these ridges delay the passage of the food.

From the stomach passes the straight intestine. Its first, narrower, shorter part is smooth-walled, and gives off dorsally a closed tube. The second, wider, longer part, has internal ridges and elevations.

The anus is inferior, longitudinal, on the telson.

(*c*) *Absorption.*—As in Mussel.

(*d*) *Circulation.*—The nearly colorless blood coagulates, and has white blood corpuscles that possess endoplasts, and show amœboid movements.

The heart is median, dorsal, just behind the stomach, and lies in a pericardium or blood-sinus. Six openings, with valves opening inwards, lead from the pericardium to the heart. From before backwards these three pairs of apertures are dorsal, ventral, lateral.

Six main arteries. One ophthalmic from the anterior, dorsal median part of the heart. Two antennary, from the anterior, dorsal, lateral region. Two hepatic, from the anterior, ventral, lateral region. One sternal, posterior. The ophthalmic supplies the eyes and small antennæ; the antennary, the large antennæ; the hepatic, the liver. The sternal has at its origin an expansion, the bulbus arteriosus, whence the superior abdominal artery is given off to run along the dorsal surface of the intestine. The main artery, however, runs down, usually on the right of the intestine, gives off an inferior abdominal branch, and then pierces the nerve-cord between the last but two and the last but one of the pairs of thoracic ganglia. It then divides into two branches that run respectively forwards and backwards between the nerve-cord and the ventral surface.

The arteries, dividing, end in lacunar spaces, the largest of which, the vena cava, is ventral and median. Thence the blood passes by lacunæ to the gills, down the outer side, up the inner, through branchio-cardiac vessels to the pericardium.

(*e*) *Respiration.*—By gills enclosed in a branchial chamber on each side bounded by the sides of the carapace, or branchiostegites. The gills are 18 pairs. Six are the modified epipodites of the somites 8—13, each with branchial filaments on the anterior edge. Twelve are attached to the epimera of somites 8—14. Segments 8 and 14 carry one gill on each side; segments 9—13 carry two. Each of these twelve is a central, longitudinal stem, giving off filaments on each side. A scoop-shaped sweep, the scaphognathite (σκαφος = boat, γναθος = jaw), attached to the second maxilla of each side, is constantly sweeping away water from the front of the gill-room, and causing indirectly a flow in at the back.

(*f*) *Secretion.*—(1) Liver. A double organ. Each half lies by the side of the stomach, is soft, yellow, elongated, bilobed, of many blind, branched tubes, lined with epithelium cells, and has a duct opening into the alimentary canal just where stomach and intestine join.

(2) Green glands. Under the anterior part of the carapace, right and left. Each has a cortical region of many cæca, and a medullary of many canals. The cæca open into the canals, and the canals into a common canal, ending in a duct opening on the inner side of a conical eminence on the under side of the basal joint of the antenna. Possibly the green glands are renal, and the cæca are the agents in separating the nitrogenous products of decay from the blood.

(*g*) *Nervous system.*—(1) Chain of ganglia. In the median line of the body are thirteen nerve-swellings connected by cords. They all lie in the same vertical plane, like the ganglia of the Mussel. The first pair is dorsal, and at a higher level than the rest, like the cephalic and parieto-splanchnic of the Mussel. The other twelve are ventral.

or scaphocerite, a long, many-jointed endopodite, of ischio-mero- carpo- pro- cerite. The last is of many pieces.

(2) Of smell. Setæ on exopodite of antennule.

(3) Of hearing. On the upper surface of the proximal joint of the antennule, among a number of hair-tufts, is an opening leading into the auditory sac. The sac's wall has gritty matter (otolithic), a ridge with hairs dilated at the base, pigmented epithelium cells. The sac's contents are fluid, with otoliths of flint (Si O^2). The hairs seem to be in contact with these otoliths, and branches of the auditory nerve reach their bases. The whole ear is the homologue of the Frog's vestibule.

(4) Of sight. The eyes, on stalks or peduncles, called ophthalmites, belong to the first somite. The peduncle is of two pieces, the basi- and pod-ophthalmite. Each eye is compound. The translucent, integumental cornea in front is divided into many nearly square facets. Consider one facet only. Immediately behind it lies a fine, granular layer, then a long, transparent, crystalline cone, then a slender rod, the connective rod, then a fusiform rod transversely marked, the striated body. The many striated bodies all perforate a membrane, and end in the optic ganglion, or dilated end of the optic nerve. Each division of the compound eye then consists of a corneal facet, a fine granular layer, a crystalline cone, a connective rod, a striated spindle. The membrane, ganglion, nerve, are common to all. A pigment membrane separates each division of the eye from its fellow. Probably the eye is homologous with the retina of the Frog.

(*i*) *Motor organs.*—Each somite of the body has its appendages. These will now be enumerated, and the motor ones will then be studied in detail.

Body Somite.	Region Somite.		Appendages.
1	Head	1	Eyes.
2	,,	2	Antennules.
3	,,	3	Antennæ.
4	,,	4	Mandibles.
5	,,	5	1st Maxillæ.
6	,,	6	2nd ,,
7	Thorax	1	1st Maxillipedes.
8	,,	2	2nd ,,
9	,,	3	3rd ,,

Body Somite.	Region Somite.	Appendages.
10	Thorax ... 4	Forceps Limbs.
11	,, ... 5	1st Chelate Limbs.
12	,, ... 6	2nd ,,
13	,, ... 7	1st Pointed Limbs.
14	,, ... 8	2nd ,,
15	Abdomen... 1	1st Swimmerets.
16	,, ... 2	2nd ,,
17	,, ... 3	3rd ,,
18	,, ... 4	4th ,,
19	,, ... 5	5th ,,
20	,, ... 6	6th ,,

Each of these appendages has typically a protopodite of two joints, and endo- exo- and epipodite, as in the maxillipedes.

Thoracic limbs. 1, 2, 3, are feet-jaws (v. s.). 1. Protopodite of one short, thick joint; endopodite, flat, leafy, many-jointed; exopodite, long, slender, many-jointed; epipodite, curved, long, plate-like. 2. Endopodite, stouter, less leafy; epipodite carries a gill. 3. As last, but endopodite still stronger and less leafy. 4. Claws. Protopodite of coxo- and basi-podite; endopodite of ischio- mero- carpo- pro-podite, the last so elongated that its inner upper corner is opposite to the terminal division of the endopodite or dactylopodite; exopodite wanting; epipodite carries a gill. 5—8, as last, save in size and termination.

Abdominal limbs. 1—6 are swimmerets. Protopodites of two joints. Endo- and exo-podites present generally; endopodite wanting in 1 of female, rolled upon itself in 1 of male, in 2 of male long and rolled upon itself; exopodite, in 1 of female concave at end on inner side; no epipodites. The tail-fin is formed by the telson and the last pair of appendages.

The muscles are intrinsic. The byssus is represented by a tuft of threads on the coxopodite of the appendages of the 9th—14th, body segments.

(*k*) *Reproduction.*—(1) Agamogenesis, unknown. Parts of the animal if removed may be restored.

(2) Gamogenesis. Unisexual. ♂ Testis yellow, lying behind stomach and under heart. Of three lobes, two lateral and anterior in contact with each other, a third median and posterior. Each lobe is of many small, blind tubes, opening into a central duct. Within the cœcal tubes

are formed motionless spermatozoa, each a cell with an endoplast and many radiating processes. The vas deferens of each side commences at the junction of the posterior single lobe with the lateral, widens, becomes convoluted, and ends on the coxopodite of the last thoracic somite. The spermatozoa aggregate in masses, each of which is surrounded by a coat, secreted by the wall of the duct, and each mass is a spermatophore. The transference of the spermatophores to the female is effected by the appendages of the first and second abdominal somites.

♀ The ovary in color and shape and position resembles the testis. It is, however, a central single sac, with three extensions, two anterior, lateral, one posterior, median. The ova are developed from the cells, forming the internal lining of the organ. The oviducts are short, wide, not convoluted. Their openings are on the coxopodites of the last thoracic appendage but two. Impregnation occurs within the mother, and the eggs acquire a viscid coat, produced at one point into a stalk, by which the egg is attached to the hairs of the swimmerets.

(*l*) *Development.*—The egg has the usual parts, and after impregnation part of it segments, forming macromeres and micromeres. The former are invaginated within the latter, and form the hypoblast containing the vitellus, as in a sac. From this sac, intestine, and liver, but not stomach, are formed. The vitellus is gradually absorbed, and the blastoderm, with its usual three layers, invests the yolk as a large disc. Anteriorly, the disk widens, and presents two lobes, the procephalic. The side edges of the blastodermic disc thicken and rise into a fold. Certain median and lateral thickenings appear on the disc. A median one in front becomes the labrum. A median one is developed posteriorly, and turns forwards under the rest of the embryonic disc. This is the thoracico-abdominal process. From it the abdomen and part or whole of the thorax are formed. Of the transverse thickenings, the three first pairs developed are the antennules, antennæ, mandibles. Then appear the eyes, anus, and mouth, and more transverse thickenings representing both pairs of maxillæ, three pairs of maxillipedes, five pairs of feet. Of these appendages, only the feet and the last of the maxillipedes are attached to the thoracico-abdominal process. This last straightens out, and is at length in the same line of direction as that of the rest of the body.

Each appendage is at first a ridge, then a plate, free at the distal end, and dividing (except in the eyestalks and mandibles) into an inner part (endopodite), and an outer, generally sub-divided (exo- and epi-podite).

The cerebral ganglia and circum-œsophageal cords appear as a ridge upon each side of the œsophagus, the anterior portion becoming the ganglia, the posterior the commissure. The cerebral ganglia are at first two on each side, the posterior and larger probably representing two conjoined. Thus we should have three pairs above the œsophagus, corresponding with the eyes, antennules, antennæ. The sub-œsophageal ganglia are at first eleven (supplying jaws and feet). The first four join: the next two join: the two compound ganglia of each side thus formed then join to form the huge first sub-œsophageal ganglia. The rest of the thoracic, and all the abdominal ganglia remain separate.

The genital glands develop later, the ducts forming centrifugally. They do not reach the exterior, and the copulatory appendages of the first two abdominal somites are not developed until some time after birth.

Ecdysis (εκδυω = I cast off) or casting of the chitinous integument occurs.

(*m*) *Classification.*—Kingdom, Animalia. As the Crayfish has a succession of somites, all built upon the same plan, a systemic heart and nerve-ganglia, chiefly on the ventral surface with the first ganglia supra- and first commissure circum-œsophageal, the sub-kingdom is Annulosa (*annulus* = ring). As the somites are twenty, and the respiratory organs are gills, the class is Crustacea. As the ambulatory limbs are ten, and the eyes are on stalks the order is Decapoda (ten-footed), or Podophthalmia (stalked-eyed). Genus, Astacus. Species, fluviatilis.

PRACTICAL WORK.—(1) Draw side view. (2) Remove carapace, and show its markings. (3) Study exoskeleton of one somite, say the third abdominal, marking all its parts. (4) Remove telson. (5) Insert bristle in mouth. (6) Remove mandibles, maxillæ (two pairs), maxillipedes (three pairs). (7) Dissect out alimentary canal. (8) Remove gastric armature. (9) Demonstrate anus. (10)

Dissect out pericardium, heart, arteries. (11) Microscopic investigation of blood. (12) Structure of a gill. (13) Scaphognathite. (14) Dissect out liver: show connexion with alimentary canal. (15) Green glands and ducts. (16) Whole of nervous system. (17) Remove antennules and antennæ. (18) The ear. (19) Longitudinal section of eye. (20) Remove every pair of appendages. (21) Name divisions of every one of them. (22) Dissect out ovary or testis. (23) Microscopic examination of ovum. (24) Trace out ducts. (25) Demonstrate openings.

The Lobster differs from the Cray-fish in the following points:—

(*a*) It occurs in rocky seas. Last thoracic somite, and last but one ankylosed: carapace has no line marking off last thoracic somite externally.

(*b*) Intestine smooth: dorsal cœcum near end of rectum.

(*l*) Testes tubular. The two long tubes lie in thorax and abdomen. One-fourth of whole length from front end a transverse branch joins them. Posteriorly, they meet in the median line. Vas deferens arises about middle of tube, is not convoluted, but dilated. Spermatozoa are long cells with three processes at one end. Ovaries like testes, but black, and in contact at anterior ends. Oviduct arises at middle of tube.

(*m*) Metamorphosis. The egg produces a larva, the Zoea, with rounded carapace destitute of appendages: long thoracic exopodites: eyes large.

(*n*) Genus, Homarus. Species, vulgaris.

CHAPTER XV.

XV. Frog.

(*a*) *Structure.*—(1) Occurrence. The common Frog of this country occurs in Scotland and Ireland, generally in Europe, in Northern Africa, Northern Asia, Northern America.

(2) General structure. I shall consider the external appearance, the exoskeleton, the internal cavities, the endoskeleton, the tissues.

(α) External appearance. The Frog has no neck, no tail. In his skin are color-patches, due to cells of various and of varying shapes, that contain pigment-granules.

(β) Exoskeleton. None, save a horny prominence on the inner margin of the sole of the foot, just at the base of the innermost toe. This is the tarsal tubercle (*tarsus* = ankle).

(γ) Internal cavities. On opening the body of a Frog a large somatic or body-cavity is found in which the chief organs lie. It is limited anteriorly by the neck, behind by the girdle for the support of the hind legs, below by muscular walls, above by the vertebral column. Lined throughout by a membrane that is reflected over the various contained organs, and that represents the pleura or lung-covering membrane and the peritoneum or membrane enveloping the abdominal viscera of man, this cavity is called the pleuroperitoneal. The organs contained in it will be considered in connexion with their respective functions. But certain yellow masses, looking like small fingers and made up of fat, must be mentioned here, as they cannot be dealt with elsewhere. They are visible on each side of the large brown liver. A rudimentary muscular ingrowth of the wall of the cavity at its anterior region in front of the lungs, and attached to the heart, is a diaphragm or partition of a very rudimentary nature. Finally, when all the viscera are removed, calcareous crystals in little white masses are seen at the upper part of the cavity on each side of the vertebral column. In the head and back are two cavities, that which contains the brain and that which lodges the spinal cord, that are practically one and the same, the narrow vertebral canal widening anteriorly into the larger brain-cavity.

(δ) Endoskeleton. Partly cartilaginous or gristly, partly osseous or bony. The cartilage that precedes bone in the higher animals is in some parts of the Frog persistent, and is not replaced by osseous tissue. The cartilage lasts upon the free, inferior surfaces of the bodies of the vertebræ, upon the ends of the transverse processes of those bones, and in the sternum. A tissue yet older and more embryonic than cartilage persists in the bodies of the vertebræ. There remnants of the notochord (see Development) are found. A considerable part of the skull is also cartilaginous, and is known as the chondro-cranium (χονδρος = cartilage). The jaw-suspensorium, or part of the skull that supports the lower jaw and links it on to the rest of the cranium, is cartilaginous, and much of the lower jaw itself is also of cartilage, known as Meckel's cartilage.

The osseous skeleton of the Frog calls for special comment. It *must* be studied from a prepared specimen. To read an account of it without the actual bones before us is useless, and worse than useless. The names of the bones are tabulated, and then a few words upon certain special bones are added. (See page 126.)

Atlas—The foremost vertebra articulating with the skull. *Centrum*—The lower solid body of the vertebra. *Articular processes*—By these a vertebra joins its fellow before and behind. *Urostyle*—The posterior, unsegmented part of the column. *Xiphisternum*—Posterior region. *Sternum proper*—Median region. *Omosternum*—Anterior region. *Clavicle*—Runs from omosternum outwards in front of precoracoid to join coracoid and scapula. *Coracoid proper*—Behind the large foramen in the shoulder-girdle. *Epicoracoid*—A cartilage lining the margin of the true coracoid where the latter meets its fellow. *Precoracoid*—In front of the foramen. *Scapula*—Forms most of the cavity for the head of the arm-bone. *Radio-ulna*—Represents the two bones of our fore-arm, the radius on the thumb side, the ulna on the little finger side. *Ilium*—Anterior, long. *Ischium*—Posterior, rounded. *Pubis*—Meets its fellow medially, ventrally. *Tibio-fibula*—Represents the two bones of our leg, the tibia on the big toe side, the fibula on the little toe side. Ex-

- SKELETON.
  - Trunk
    - Vertebral column
      - Atlas.
      - 2nd—8th each with
        - Centrum.
        - Neural arch.
        - Spinous process.
        - Transverse processes.
        - Articular processes.
      - Sacrum with sacral ribs.
      - Urostyle.
    - Thorax, of Sternum
      - Xiphisternum.
      - Sternum proper.
      - Omosternum.
  - Extremities.
    - Upper
      - Arch, with on each side
        - Clavicle
        - Coracoid
          - Coracoid proper.
          - Epicoracoid
          - Precoracoid.
        - Scapula
          - Supra-scapula.
          - Scapula proper.
      - Limb
        - Humerus.
        - Radio-ulna — 2 bones conjoined.
        - Carpus — 7 bones.
        - Metacarpus — 5 bones.
        - Phalanges — 10 bones.
    - Lower
      - Arch
        - Os innominatum
          - Ilium, Ischium, Pubis — meeting in acetabulum.
      - Limb
        - Femur.
        - Tibio-fibula — 2 bones conjoined.
        - Tarsus
          - 2 long bones, astragalus, calcaneum.
          - 2 cartilages bearing calcar.
        - Metatarsus — 5 bones.
        - Phalanges — 14 bones.
  - Skull
    - Head
      - Occipital — 2 ex-occipitals.
      - Parieto-frontals.
      - Temporals
        - 2 pro-otics.
        - 2 squamosals.
        - 2 pterygoids.
      - Sphenethmoid.
      - Parasphenoid.
    - Face
      - Nasals.
      - Superior maxillaries
        - Premaxillæ.
        - Maxillæ.
      - Quadrato-jugals.
      - Palatines.
      - Vomers.
      - Mandible
        - Meckel's cartilage.
        - Angulo-splenial.
        - Dentary.

occipitals—Carry the two prominences or occipital condyles, that rest on the atlas. *Parieto-frontals*—Represent our parietal, or side-bones of the skull, and our frontal, or fore-head bones, conjoined. *Temporal*—The "temple" bone of man is here broken up into the pro-otic (προ = before, 'ους = ear), lodging the internal ear, the squamosal (*squama* = scale) corresponding with the flat, external part of our temporal, the pterygoid (wing-like) representing a process in man. *Sphenethmoid*—The human sphenoid, or wedge-shaped bone, conjoined with the ethmoid, or sieve-like bone, that forms the upper part of the partition between the two nasal cavities, their roof and part of their outer wall in man. *Para-*

sphenoid—Dagger-shaped, median, basal; not represented in man. *Quadrato-jugal*—The malleus, or first ossicle of hearing, and the cheek-bone of man.

In addition to these classified bones, the hyoid bone, or cartilage, representing the gill arches of the fish, is present.

(ϵ) Histology.—*Bone.*—Of calcium phosphate principally, with some calcium carbonate and other salts. These together constitute about two-thirds of bone. The other one-third is animal matter in the form of gelatin. The hard tissue thus constituted is arranged in cylinders around longitudinal canals containing blood-vessels. The bony cylinders are lamellæ; the longitudinal canals are Haversian canals. The lamellæ, concentric with a canal and with each other, are traversed by fine canaliculi, carrying the blood-fluid from the vessel in the canal into the substance of the bone. Between the lamellæ these canaliculi expand into larger, wider, broader spaces, the lacunæ.

Fat or Adipose Tissue.—Within the bone is marrow, or fat. This tissue, met with in other parts of the body, is of rounded cells, containing oil, and held together by blood-vessels and connective tissue.

Fibrous Tissue.—Covering the bone is a membrane, the periosteum. This is a fibrous membrane. The tendons and the subcutaneous bands are of fibrous tissue. Its elements are white, non-elastic, unbranched fibres, best seen in the white tendons in which muscles end, and destroyed by acetic acid; yellow, elastic, branched fibres, best seen in the subcutaneous bands, and unaffected by acetic acid; protoplasmic corpuscles.

Cartilage.—The ends of the bones are coated with cartilage. A matrix, structureless or granular, containing nucleated cells.

Muscle.—The bones are clothed with voluntary, striated muscle. These are of fibres. The fibre has an outer membrane enclosing smaller fibres (fibrillæ).

Nerve Tissue.—The muscles are supplied with nerve-fibres. Each nerve-fibre is of smaller fibres. The ultimate fibres have an outer membrane (primitive sheath) enclosing a fat-cylinder (medullary sheath), and within the latter an axis-cylinder. The nerve-fibres run into the spinal cord and brain, and these central organs contain many nerve-cells, large, granular, nucleated.

Epithelium.—All the structures are invested externally by the skin. The internal lining of all organs is a tissue resembling the skin. The skin and this internal lining are epithelial membranes. They present superficially a layer of cells supported on a more deeply-placed basement membrane, resting in its turn on fibrous tissue, containing vessels and nerves. The epithelial tissues are distinguished by the nature of their cells. In squamous epithelium the cells are flat, *e.g.* skin (many layers forming stratified epithelium), pleuro-peritoneal membrane (one layer, simple epithelium). Columnar, *e.g.* cells long, nucleated lining of intestinal canal. Ciliated, *e.g.* cells rounded, nucleated, with cilia on their free edge lining respiratory tract. Spheroidal, *e.g.* cells round, secretory lining interior of glands.

(*b*) *Digestion.*—Food. Organic, animal. The angle of the mouth extends beyond the eye. The recurved, pointed teeth are upon the vomers, premaxillæ, maxillæ, not on the mandible. The parts of the alimentary canal are in succession: œsophagus, an elongated stomach, with internal longitudinal folds, an intestine presenting a narrow duodenum running parallel to the stomach, a narrow ileum, coiled, to the right, with internal transverse folds, a broad colon, with a dilatation representing the cœcum of man, a rectum or cloaca, receiving also the renal and reproductive products and opening externally on the back. The intestine is slung up to the vertebral column by two parts of the pleuro-peritoneal membrane, that passing upon each side of the vertebral column superiorly are attached to the intestine below, and form thus the mesentery.

(*c*) *Absorption.*—(1) Of food. Special vessels, the lacteals, commence blindly within elevations of the walls of the intestine, called villi. These absorb the digested food, and pour it into the blood system *viâ* two ducts, that run up the body cavity, and enter the venous system close by the heart. The fluid contents of the lacteals are chyle. (2) Of unused blood. Blood poured out from the capillaries in the tissues, and not used by these, is absorbed by a special set of vessels, the lymphatics, distributed through the body generally. These empty themselves into the two thoracic ducts mentioned above. The fluid they carry is lymph, clearer than chyle, with less fat, with many amœboid corpuscles. The lymphatic system has many large dilatations. Thus between the two parts of the pleuro-peritoneal membrane that make the mesentery, beneath the skin and within the serous membranes, such spaces occur. Two pairs of *contractile* dilatations, called lymph-hearts, one anterior, near the transverse processes of the third vertebra, the other posterior, near the urostyle, put the absorbent system into connexion with that system of blood-vessels of which it is but a specialised portion.

(*d*) *Circulation.*—(1) Blood. Of fluid serum and solid corpuscles. The corpuscles are white, (v. s.) $\frac{1}{100}$ m. m., and red. The red are oval, nucleated, $\frac{1}{60}$ m. m. (2) Organs. The heart, invested by the membranous pericardium, has behind a sinus, in which the veins end; above, two auricles, the right connected with the sinus venosus, the left with the vessel returning the aërated blood from the lungs; below, a single ventricle, into which both auricles open; in front a bulbus arteriosus, communicating with the right, anterior region of the ventricle. Between each of the two auricles and the one ventricle is a single fold, or valve, permitting the blood to flow from the auricle to the ventricle, but not in the opposite direction. Between the bulbus and ventricle are three valves. The bulbus is at first simple (pylangium): then (synangium) partly divided by a longitudinal fold affixed superiorly to the dorsal wall of the bulbus, but free inferiorly and ventrally. Three more valves occur at the junction of the pyl- and syn-angium. The synangium is thus partly divided into right and left parts. From the left leads off a passage to the two arteries that carry blood to the lungs (pulmonary). From the right, the arteries to the body generally (aortæ), and to the head (carotid) pass. A table of the chief arteries and chief veins follows.

ARTERIES.	Bulbus arteriosus.	Posterior arch... ...	Pulmonary.		
			Cutaneous.		
		Middle (aortic) ...	Vertebral.		
			Subclavian.		
			Œsophageal.		
			Cœliaco-mesenteric	Cœliac ...	Stomach.
					Liver.
				Mesenteric	Intestine.
					Spleen.
			Adrenal.		
			Renal.		
			Genital.		
			Dorsal.		
			Common iliac	Hypogastric.	
				Femoral.	
		Anterior	Lingual.		
			Carotid.		

VEINS.			Internal jugular ...	Vena innominata	Vena cava superior	Venous sinus,
			Subscapular			
			Musculo-cutaneous .	Subclavian		
			Brachial			
			Mandibular	External jugular...		
			Lingual			
	Femoral Sciatic.	Dorsal pelvic ...	Common iliac	Renal	Vena cava inferior	
			Dorso-lumbar			
		Ventral pelvic = Anterior abdominal ...		Hepatic		
			Hepatic capillaries ..			
		Gastric	Vena portæ			
		Lieno-intestinal				
				Genital		

(3) Course of circulation. The venous blood from the body enters the venous sinus, and passes to the right auricle. The arterial blood from the lungs, returning by the pulmonary veins, passes to the left auricle. Both auricles open into the ventricle. As the bulbus arteriosus is attached to the right region of the ventricle, the first blood that enters the bulbus as the ventricle contracts is venous. This flows through the pulmo-cutaneous, or posterior arch, to the lungs and skin. As the bulbus contracts, the incomplete partition becomes temporarily complete, and the blood now flows up the right of the septum into the aortic, or middle arch. This receives mixed blood from both auricles. Finally, in the last stages of the ventricular contraction, the good, left-side blood that cannot pass into the respiratory vessels, as they are shut off by the partition, nor into the aortic, as they are full, passes into the carotid, or anterior arch, and so to the head. Through arteries to their branches, to the capillaries, and the veins, the blood flows to the sinus venosus again.

(*e*) *Respiration.*—The lungs and the skin are respiratory organs. Air is taken into the lungs by an act akin to swallowing. Passing in at the nostrils, through the mouth, down the very short trachea, or windpipe, it enters *viâ* the right or left bronchus into the right or left lung. Each lung is an elastic sac, partially divided by partitions, or septa, that are much more numerous in the anterior part of the organ. On the walls of the imperfect cavities thus formed, the pulmonary capillaries full of venous blood ramify. This blood is thus brought into close relationship with the air, receives thence oxygen, and gives up to the air carbon dioxide and steam. A like exchange of gases takes place at the general surface of the body.

(*f*) *Secretion.*—(1) Liver. A large gland of a right undivided lobe and a left lobe divided into two. The right and left lobes are united by a bridge of liver-structure dorsally and anteriorly. The hepatic artery supplies the liver with arterial blood. The vena portæ brings a special blood-supply that has already passed through the capillaries of certain viscera. The hepatic vein carries away the effete blood from both these two vessels. The hepatic duct conveys the bile, that has been secreted by the nucleated hepatic cells that fill up the spaces between the branches of the vessels, to the duodenum at some little distance from the stomach. The bile, when digestion is not going on, regurgitates from the hepatic duct into the gall-bladder that lies on the dorsal aspect of the right lobe of the liver.

(2) Vascular glands. These are glands without ducts, but well-supplied with blood. They probably are manufacturers of blood, for the liquid in the veins that quit them is richer in corpuscles and in serum-contents than that in the arteries that enter them. The spleen to the left side of the somatic cavity, the adrenal bodies on the inferior or ventral face of the kidneys, the thymus behind the jaw suspensorium, the thyroid attached to the lingual vessels, the pineal and pituitary bodies connected with the brain are ductless or vascular glands.

(3) Kidneys. Two, reddish, of many tubules, whose commencements are dilated, and contain a knot of blood-vessels. These tubules gather together into one common tube, the ureter, that passes from the outer edge of the kidney downwards. The ureter opens into the posterior wall of the cloaca in the male, joins the oviduct in the female. The urinary bladder opens into the cloaca at the anterior wall of the latter.

(4) Connected with the eyes are a Harderian gland just beneath one of the upper muscles of each eye, and an interocular gland, spheroidal with small cells, opening on the skin.

(5) The skin generally has many depressions, or cæca, distributed over its surface.

(*g*) *Nervous System.*—(1) Sympathetic system. Ten pairs of ganglia lying in a double row on the ventral aspect of the vertebral column. The ganglia are connected with the spinal nerves and with the posterior cranial nerves. The sympathetic nerve-fibres pass from the ganglia to the blood-vessels, and probably indirectly regulate the diameter of these.

(2) Spinal system. The spinal canal lies within the vertebral column ending in the brain anteriorly, in a fine thread, the filum terminale, posteriorly. Two longitudinal grooves, in front and behind, divide it partially into two halves, right and left. It is of white nervous matter (nerve-fibres) externally, of grey (nerve-cells) internally. Ten pairs of spinal nerves are given off, each with two roots. The inferior root contains only efferent or motor fibres; the superior, which has a ganglion, only afferent or sensory fibres. The 1st pair of nerves are hypoglossal, and supply the tongue. 2nd and 3rd form the plexus for the arm. 4th–6th supply body-wall. 7th–9th form the plexus for the leg. 10th supplies the posterior region of the body.

(3) Cranial system. Within the skull, from behind forwards, the brain presents—(α) Medulla oblongata, centre of special nerves connected with circulation and respiration. (β) Cerebellum, co-ordinator or grouper of muscular movements. (γ) Optic lobes, centres of sense of sight. (δ) Thalami optici, centres of general sensory nerves. (ε) Cerebral hemispheres, the lower parts of which represent the corpora striata of man, and are centres of general motor nerves; the upper parts are connected with intellectual functions. (ζ) Olfactory lobes, centres of sense of smell. Within the two cerebral hemispheres are two cavities, the 1st and second, or lateral ventricles; between the two thalami optici is the 3rd ventricle; above the medulla is the 4th. A table of the cranial nerves follows :—

No.	Name.	Distribution.	Function.
1	Olfactorii	Nasal sacs	Special Sensory of Smell.
2	Optici	Eyes	Special Sensory of Sight.
3	Motores Oculorum	Muscles of Eye	Motor.
4	Pathetici	Superior oblique of Eye	Motor.
5	Trigemini	Orbit, Nose, Mouth, Face	Motor and Sensory.
6	Abducentes	Joins Orbito-nasal of last	Motor.
7	Faciales	Face, Thyroid Muscles	Motor.
	Auditorii	Ear	Special Sensory of Hearing.
8	Glossopharyngei	Tongue	Motor and Sensory.
	Vagus or Pneumogastric	Larynx, chief Viscera	

(*h*) *Sense Organs.*—(1) Touch. The skin is well supplied with nerves. (2) Taste. The tongue, fixed in front to the mandible, free behind, has elevations or papillæ, supplied with nerves. Some of the papillæ are filiform or threadlike in shape, others fungiform or contracted at the base and broader at the free end. (3) Smell. The anterior nares or nostrils lead into two nasal cavities lined with epithelium supplied by branches of the olfactory nerve. These nasal sacs open behind into the mouth close to the vomerine teeth. (4) Hearing. The drum of the ear or membrana tympani is seen on the side of the head, flush with the surface of the skin. It is lined externally by skin, internally by mucous epithelium. Internally it is joined on to a slender bone, the columella, representative of our stapes. The inner end of this bone abuts on the cartilaginous periotic capsule. Within this capsule is a fluid (perilymph) in which lies the membranous labyrinth of three canals that open into a common sac, the vestibule. In the walls of the vestibule are otoliths, and branches of the auditory nerve are distributed over the walls of the membranous labyrinth. A fluid, the endolymph, fills the vestibule and canals. When the membrane of the tympanum is set vibrating by sound-waves from without, the columella is moved, and its inner end, vibrating, sets in motion the endolymph, whose waves strike on the ends of the branches of the auditory nerve. The cavity between the membrane of the tympanum and the periotic capsule, a cavity traversed by the columella, is in communication with the throat by two wide passages, the Eustachian recesses. (5) Sight. Each eye has eight muscles, four straight, the upper, lower, internal, external recti, two oblique, the upper and lower obliqui, one retractor of the eye, one for moving the lower eyelid. The lower eyelid is semi-transparent, and really represents the little red fold at the inner corner of our eye. The coats of the eye are three. Sclerotic, hard, cartilaginous, external, protective. Choroid, delicate, vascular, pigmented, flattened in front to form the iris or colored part that is perforated centrally by a hole, the pupil. Retina, internal, of many layers containing nerve-fibres, nerve-cells, rods and cones. This is the sensitive layer. The lenses are three. Aqueous, between the cornea, or transparent front part of the sclerotic, and the iris. Crystalline, behind the pupil. Vitreous, filling up the larger part of the globe of the eye.

(*i*) *Motor organs.*—Four legs moved by voluntary, striped muscles. There are no nails. The "big" toe, or hallux, is the shortest. In the male, the skin upon the under surface of the thumb swells and secretes a viscid fluid at breeding-times.

The vocal sacs open opposite the Eustachian recesses upon the inner side of each half of the mandible. Two folds of the mucous membrane of the mouth at the upper part of the trachea form the glottis, and contain the two arytenoid cartilages that join on to a laryngo-tracheal cartilage, forming the wall of the larynx or voice organ. The vocal ligaments, whose vibration intensified by the vibration of the air in the Eustachian recesses gives rise to the voice, are two folds between those just mentioned.

(*k*) *Reproduction.*—The Frog is unisexual. ♀ Two ovaries, hollow, lamellar organs divided internally into many loculi. In the walls of these ovisacs are formed, and the ova are discharged into the interior of the organ. The duct of each ovary is not in direct continuity with the organ. It begins between the attachment of the diaphragm to the pericardium and the liver. The long, convoluted duct becomes dilated, thin, transparent below just before it opens upon the dorsal wall of the cloaca. ♂ Two testes, solid, rounded yellow organs with pigment on the exterior. Each is of many tubes, each of whose epithelial lining-cells develops many linear spermatozoa. The tubes gather together into several vasa efferentia that run into the kidney, whose ureter therefore is the passage, not only for the urine, but for the spermatozoa. Near the kidney, upon the outer side of the ureter, is a gland-mass with many minute ducts that open into the ureter. This is the vesicula seminalis. At the breeding time the swelling on the under surface of the thumb of the male becomes much enlarged, and secretes a viscid fluid, by which the animal adheres to the back of the female. As the latter lays the eggs, the male impregnates them.

(*l*) *Development.*—The egg is coated with a viscid albumen or "white" secreted by the oviduct, and swelling up in water. It has many germinal spots, and half the vitellus is pale, half opaque and colored. By the usual processes the gastrula stage is reached and the three layers of the epiblast formed. From the epiblast all epidermal structures and the cerebro-spinal nerve-centres are formed: from the hypoblast all epithelial internal linings: from the mesoblast all structures between the skin and epithelium. A groove along one region, affecting the epiblast and mesoblast, is the primitive trace; its boundaries are the laminæ dorsales. The groove, closing over, becomes the spinal canal, traversing the centre of the spinal cord and forming the ventricles. Its walls are of epiblast, and from them are developed the brain and spinal cord. In the thickness of its floor appears the notochord, a rod of tissue around which the centra of the vertebræ that make up the backbone are developed. The mesoblast in the side and inferior regions of the embryo splits into two concentric layers. The outer or parietal conjoins with the epiblast that lies on its exterior, and thus is formed the somatopleure or body wall. The inner or visceral conjoins with the hypoblast that lies on its interior, and thus is formed the splanchnopleure, or wall of the intestinal canal. The cavity between the somato- and splanchno-pleure is the somatic, and other organs are formed by outgrowths of its internal lining. At the anterior part of each side of the developing embryo thickenings appear, and the somato-pleure between these thickened ridges thins away. Thus are formed the branchial arches and branchial clefts. The first arch is the half of the lower jaw on each side.

When the young animal quits the egg it is a tadpole, or, in reality, a fish. The chief differences between the tadpole and frog will now be summarised under the usual heads. (*a*) Adhesive discs or suckers on the ventral surface behind the mouth. No osseous structures. (*b*) Food, vegetable. Mouth with a horny beak: no teeth. Intestine relatively much longer than in the adult. (*c*) — (*d*) Only one auricle receiving venous blood from the body. The bulbus arteriosus gives off three pairs of vessels, but all go directly to the gills. The six returning vessels, bringing back aërated blood from the gills, all unite into one dorsal aorta. (*e*) At first three pairs of external gills on the branchial arches: the branchial clefts open into the mouth. Later two folds of skin (opercula) grow over the external gills, leaving one opening on the left hand side of the throat. The external gills thus enclosed wither away, and internal ones are formed on the parts of the branchial arches immediately bounding each cleft. (*f*) — (*g*) — (*h*) The lip has papillæ. (*i*) At first there are no limbs, but a long, active tail. Later the anterior limbs, then the posterior appear, and the tail vanishes.

It will be easy for the student to sum up for himself the changes undergone by each organ as the tadpole becomes a frog. The only difficulty may be as to the heart and arteries. Each branchial artery, however, is connected with the corresponding branchial vein by a vessel, the ductûs botalli. As development advances these ducts enlarge, and blood flows through them instead of passing out to the gills. Thus by degrees less and less blood goes to the gills, and these wither, whilst the three pairs of branchial arteries, of ductûs botalli, and of branchial veins are transformed into the three arches of the adult bulbus arteriosus.

(*m*) *Classification.*—Kingdom, Animalia. As the Frog has a backbone, it is of the sub-kingdom, Vertebrata. As it undergoes a metamorphosis, the class is Amphibia. Without a tail, order, Anoura. Genus, Rana. Species, temporaria.

PRACTICAL WORK.—(1) Study all external openings. (2) The skeleton. (3) Histology of each tissue. (4) Make out teeth. (5) Parts of alimentary canal. (6) Lymph-spaces. (7) Lymph-hearts. (8) Lymph under microscope. (9) Blood under microscope. (10) Parts of heart. (11) Dissection of arches of bulbus. (12) Of branches of aorta. (13) Of chief veins. (14) Circulation in capillaries under microscope. (15) Lungs. (16) Lobes of liver. (17) Its vessels. (18) Hepatic cells. (19) Relations of spleen. (20) Its histology. (21) Dissection of kidneys, ureters, and cloaca. (22) The sympathetic chain. (23) A spinal nerve. (24) The brain. (25) Papillæ of tongue. (26) Parts of ear. (27) Of eye. (28) Ovaries. (29) Their ducts. (30) Testes. (31) Ova. (32) Segmentation of yolk. (33) The tadpole.

QUESTIONS IN GENERAL BIOLOGY.

(*From the South Kensington papers.*)

In what part of the body is the nervous system of the Cray-fish or Lobster placed, and of what parts is it composed? What are the chief uses of a nervous system? (See pages 117, 118, 62.)

Describe the structure of any flowering plant. In what part of the flower is the seed formed? What events must take place before a flower "goes to seed"? (See pages 85—87, 90, 91, 94, 95.)

Describe the movements of a Fresh-water Polype, and explain how they are brought about. By what methods, natural and artificial, may the multiplication of these Polypes be effected? (See page 63; pages 63, 64.)

What is the nature of the green film so often seen on trees and walls in damp situations? Explain the means by which such a film is enabled to spread and increase as rapidly as it does. What are the reasons for regarding it as a plant? (See pages 28, 31–32.)

What is meant by a mycelium? Describe the mycelium of Penicillium, and explain how it is formed and to what structures it gives rise? (See pages 43, 46, 44 and 46.)

What are fibro-vascular bundles? Of what are they formed? What purposes do they serve? (See pages 72, 73, 76, 77.)

Explain the manner in which a Fresh-water Mussel breathes. What happens when a Fresh-water Mussel is placed in water which has been thoroughly boiled and allowed to become cold? (See page 104.)

Describe the structure and action of the heart, and the cause of the circulation in the Cray-fish or Lobster. (See page 116.)

Explain the way in which a young plant of Chara grows into a large plant. In what respects is the mode of growth of a leaf of Chara different from that of the stem or of a branch? (See pages 53, 58.)

Of what various tissues is the leg of a Frog made up? What are their several uses? (See pages 127, 128.)

An infusion of hay, if freely exposed to the air, speedily becomes turbid. What is the cause of the turbidity? By what simple experiment may the turbidity be prevented, and what does the success of the experiment show? (See page 10.)

Describe and explain the manner in which the bell animalcule obtains, swallows and digests its food. (See pages 36, 37.)

ORIGINAL QUESTIONS.

Point out the resemblances and differences between the white-blood corpuscle and (*a*) the red-blood corpuscle, (*b*) Amœba. (See pages 17—22.)

How is the feeding and how is the breathing of the following living beings effected—Amœba, Saccharomyces, Vorticella? (See pages 19—21, 25, 26, 29, 30.)

Where would you look for the spermatozoids of Chara? What is the result of their reaching the nucule? (See pages 56—58.)

What are the mesentery of the Sea-Anemone and that of the Frog? What are the pericardium of Anodonta and that of Rana respectively? (See pages 66, 124, 129, 103, 129.)

Describe the parts met with in a Fern prothallium. (See page 79.)

Name and describe the chief histological elements in a flowering plant. (See pages 72, 73.)

Compare the eye of a Cray-fish with that of a Frog. (See pages 119, 133.)

Enumerate the parts of the brain of a Frog with their possible functions. (See page 132.)

D. GLOSSARY.

[*N.B.—Derivations are given in the text.*]

	PAGE
Aboral.—The opposite end of the body to the mouth	69
Adipose tissue.—Fatty tissue	127
Adrenal bodies.—Vascular glands near kidney	131
Adventitious.—Non-axillary buds	84
Adventitious.—Secondary roots	82
Agamogenesis.—Asexual reproduction	15
Anatropous.—Inverted	94
Andrœcium.—Collection of stamens	90
Annulus.—Ring of sporangium	78
Anther.—Upper part of stamen	90
Antheridium.—Male organ of Cryptogamia	56, 79
Antherozoids.—Fertilising agents in Cryptogamia	56, 79
Archegonium.—Female organ of Cryptogamia	59, 79
Ascospore.—Spore formed in an ascus	27, 46, 48
Ascus.—Spore case	46
Atropous.—Erect	93
Axial.—Primary	82
Axile.—Meeting in centre of ovary	92
Axilla.—Angle between leaf and stem	51
Axillary.—In the angle between leaf and stem	84
Axis-cylinder.—Central, essential part of nerve-fibre	127
Basicerite.—Second joint of antenna	118
Basiophthalmite.—First joint of eye-stalk	119
Basipodite.—Second joint of claws	120
Biology.—The study of living things	7
Bisexual.—With both sexes in the same individual	55
Branchiæ.—Gills	104, 117
Branchiostegite.—The side of the shell, covering gills	117
Bronchus.—Division of trachea	130
Calyptrogen.—Outermost layer of meristem	96
Calyx.—Outermost whorl of complete flower	86
Campylotropous.—Horse-shoe shaped	94
Capitella.—Small cells or capitulum	57
Capitulum.—Cell at inner end of manubrium	57
Carapace.—Shell of Crayfish	112
Carpels.—Female organs of flower	90, 93
Carpocerite.—Third joint of endopodite of antenna	119
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Cell.—Nucleated protoplasm surrounded by a membrane ... 35
Cellulose.—The substance of the vegetable cell wall 24
Chalaza.—Point of union of podosperm and seed-coats ... 93
Chlorophyll.—Green color-matter of plants 29, 52, 59
Choroid.—Pigment coat of eye 133
Chromatophores.—Eye spots 68
Chyle.—Fluid in lacteals 128
Cirrinate.—Coiled at apex 79
Cloaca.—The last region of the alimentary canal when renal or genital products also traverse it 102
Columella.—Extension of hypha into an ascus ... 47, 49
Columella.—The bone of the middle ear 133
Conidia.—Naked spores of Penicillium 46
Conidiophores.—Hyphæ carrying conidia 46
Connective.—Median portion of anther 92
Cornea.—Transparent, anterior part of sclerotic 133
Corolla.—Second whorl of complete flower 97
Corona.—Tip-cells of spiral outer layer of archegonium ... 56
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Coxocerite.—First joint of basal part of antenna 118
Coxopodite.—First joint of basal part of claw 120
Craspedum.—Thickened edge of free part of mesentery ... 67
Crystalline lens.—Chief lens of eye 133
Cuticle.—Outer layer of Infusoria 35
Cytod.—Protoplasm non-nucleated, surrounded by a membrane 11, 24

Dactylopodite.—Terminal joint of endopodite of claw 120
Dehiscence.—Opening, of anthers, or of fruit 92
Dermatogen.—Second layer of primary meristem of root ... 96
Diaphane.—Cortical layer of Infusoria 35
Diaphragm.—Muscular partition across body cavity of Vertebrata 124

Ecdysis.—Moulting of shell 122
Ectoderm.—Outer layer of body-wall of Cœlenterata 59
Ectosarc.—Outer layer of protoplasm 19
Endoderm.—Inner layer of body-wall of Cœlenterata 59
Endoplast.—Protoplasmic nucleus of cell 19, 35
Endoplastule.—Nucleolus 19, 35
Endopodite.—Internal process of protopodite 115
Endosarc.—Inner protoplasm of Amœba 19
Endospore.—Inner coat of spore 93, 48, 78
Endothecium.—Inner coat of anther 92
Enterocœle.—A cavity partly somatic, partly gastric 67
Epiblema.—Epidermis of root 82
Epipodite.—External process of protopodite 115
Epithelium.—Internal and external lining 127
Exopodite.—Middle process of protopodite 115
Exospore.—Outer coat of spore 48, 78
Exothecium.—Outer coat of anther 92
Extine.—Outer coat of pollen-grain 93

Fibre.—An elongated, hard-walled cell 72
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